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CENTRAL BASIN OF APPALACHIAN GEOSYNCLINE[1]

ROBERT C. LAFFERTY[2]
Charleston, West Virginia

ABSTRACT

This paper has for its purpose the summary and critical examination of existing information and opinion relative to the structure and stratigraphy of the central part of the Appalachian geosyncline.

The Appalachian geosyncline is made up of three major basins of deposition: (1) a Northern basin with its deepest point near Altoona, Pennsylvania; (2) a Central basin with its deepest point near Elkins, West Virginia; and (3) a Southern basin with its thickest sediments centered near Birmingham, Alabama. This paper is concerned only with the Central basin.

Two cross sections, showing sequence, thickness, and areal distribution of the rocks as far as known by drilling, are given. One of these is drawn transverse to the major axis of the Appalachian geosyncline and traverses the deeper part of the Central basin from northwest to southeast. The other roughly parallels the major axis of the Appalachian geosyncline and traverses the west flank of the Central basin from northeast to southwest.

INTRODUCTION

Figure 1 shows by means of contours the relative sizes and shapes of the three major basins making up the Appalachian geosyncline. These are (1) a Northern basin with its thickest sediments near Altoona, Pennsylvania; (2) a Central basin with its thickest sediments near Elkins, West Virginia; and (3) a Southern basin with its thickest sediments near Birmingham, Alabama. Northwest of this negative area and roughly paralleling it, lies the older positive element known as the Cincinnati arch. The Appalachian structural front is considered to mark the thickest deposition of the Appalachian basins. This paper deals only with the Central basin.

The outline of the basin represented by presently exposed Permian beds, as shown in Figure 2, has been compiled from the various

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[2] Assistant geologist, the Owens, Libbey-Owens Gas Department. The writer is indebted to O. Fischer of the Owens, Libbey-Owens Gas Department; A. Y. Barney, of the Columbian Carbon Company; and J. R. Lockett, of the Ohio Fuel Gas Company, for reading and criticizing the manuscript.

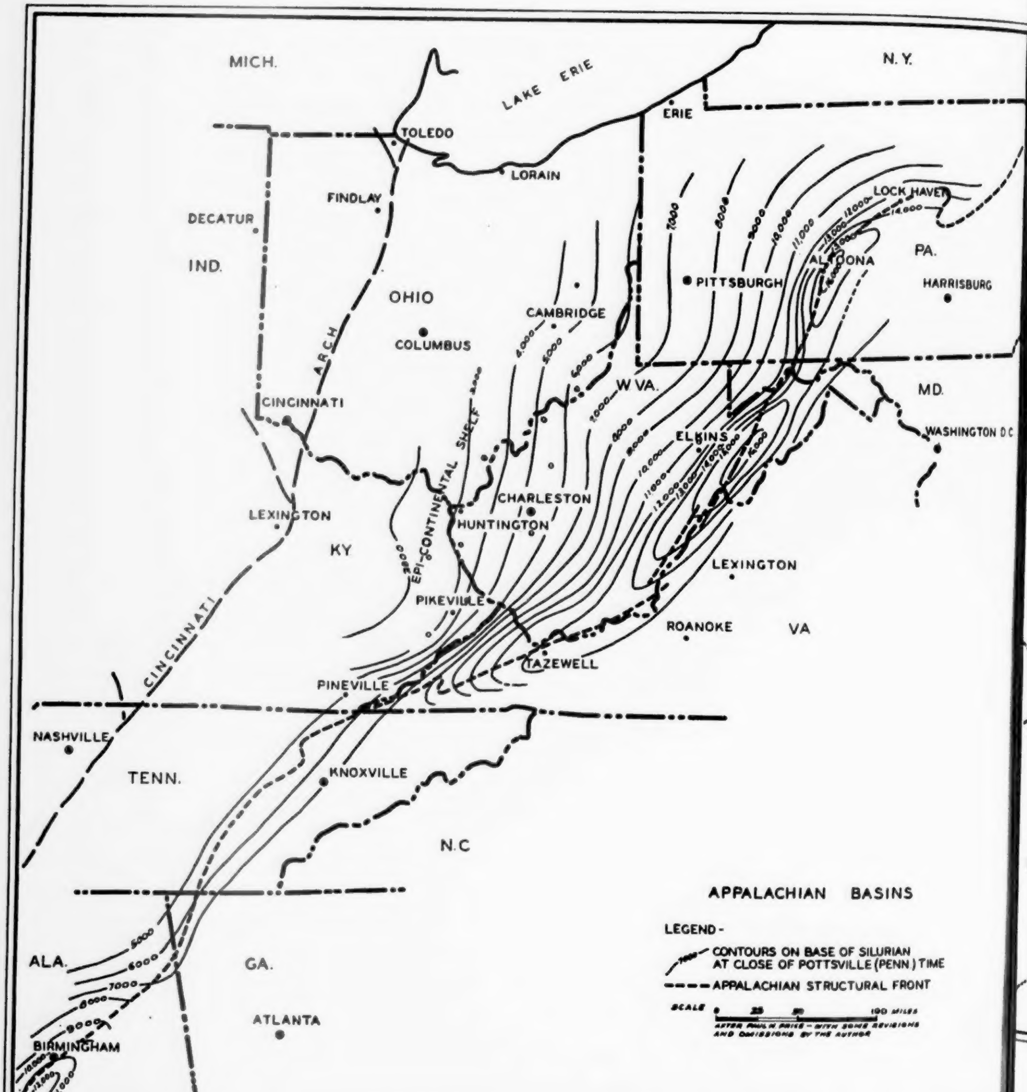


FIG. 1.—Map showing thickness of Silurian, Devonian, Mississippian, and Pottsville (lower Pennsylvanian) sediments deposited in Appalachian geosyncline. Map from Paul H. Price, "The Appalachian Structural Front," *Jour. Geol.*, Vol. 39, No. 1 (January–February, 1931).

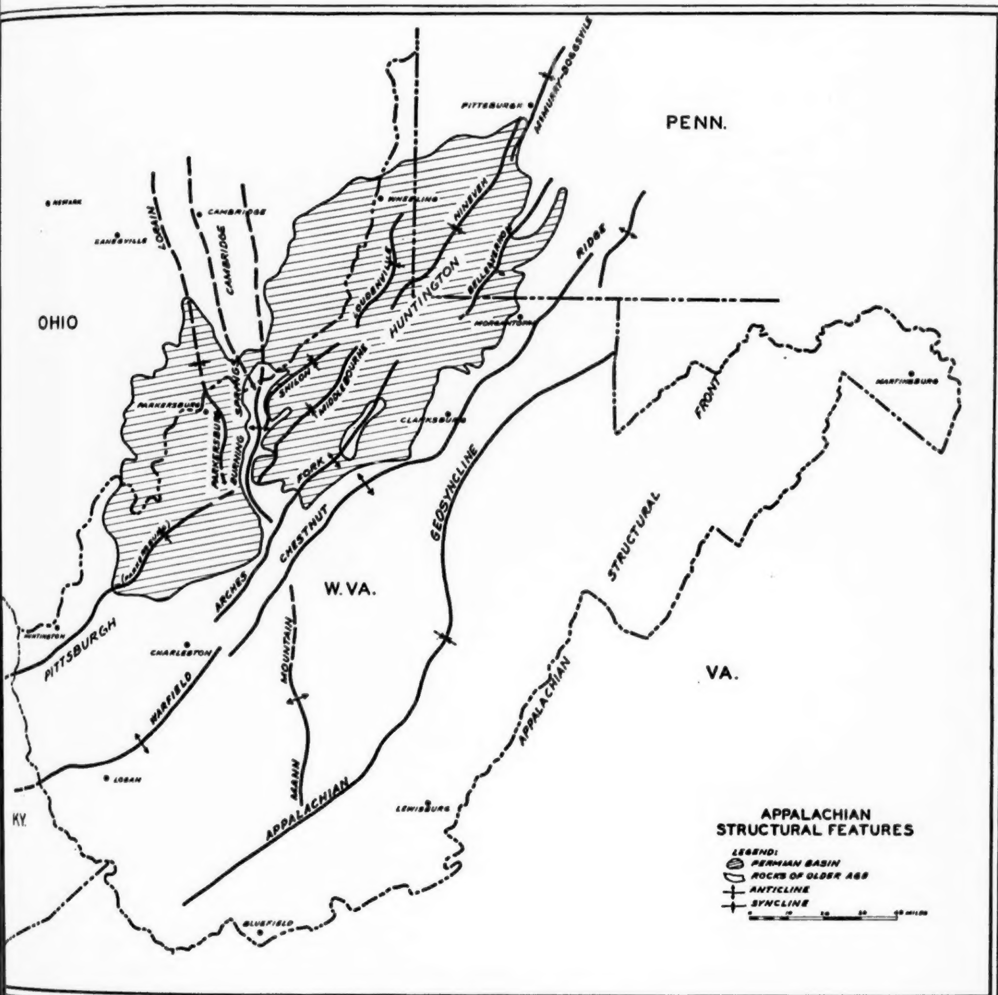

PENN.
OHIO
W. VA.
VA.
KY.
PITTSBURGH
WHEELING
NEWARK
ZANESVILLE
CAMBRIDGE
LORAIN
NINEVEH
HUNTINGTON
MORGANTOWN
PARKERSBURG
BURNING SPRINGS
SHILOH
MIDDLEBOURNE
FORK
CLARKSBURG
MARTINSBURG
CHESTNUT
RIDGE
ARCHES
PITTSBURGH
HUNTINGTON
CHARLESTON
WARFIELD
MOUNTAIN
MANN
LOGAN
GEOSYNCLINE
APPALACHIAN
STRUCTURAL
FRONT
APPALACHIAN
LEWISBURG
BLUEFIELD
APPALACHIAN
STRUCTURAL FEATURES
LEGEND:
PERMIAN BASIN
ROCKS OF OLDER AGE
ANTICLINE
SYNCLINE

FIG. 2

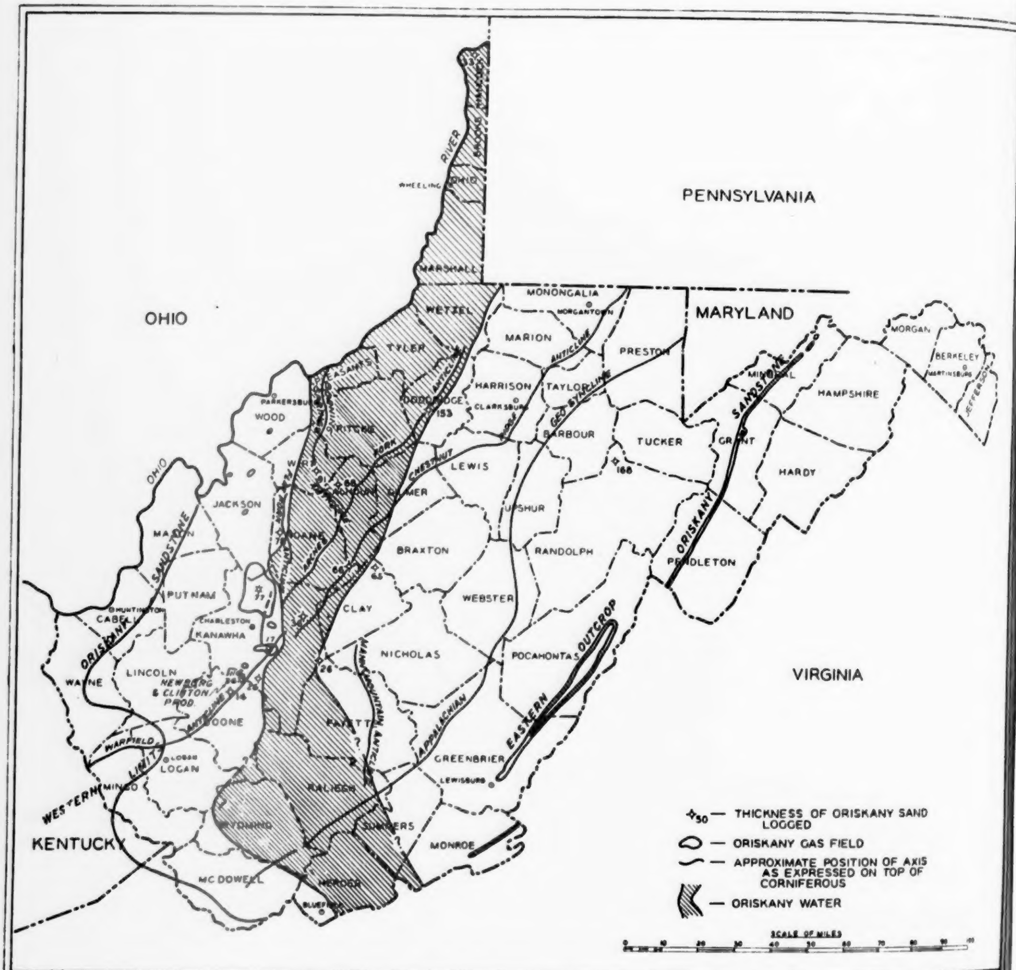


FIG. 3.—Map showing structural and depositional features as expressed in the Oriskany sandstone (Lower Devonian) in West Virginia.

State areal geologic maps covering the area under discussion. The positions of structural features, with the exception of the Appalachian structural front and Appalachian geosyncline, are taken from various State publications, but have been changed where necessary to comply with the writer's mapping. The position of "The Appalachian Structural Front" is taken from a map published in connection with a paper of the same title by Paul H. Price.[3] The position of the Appalachian geosyncline is as mapped by the writer.

It is generally accepted that the Appalachian foreland region has been a negative or subsiding area throughout practically the entire period of its development. If this assumption is correct the axis of the Appalachian geosyncline should be found to have migrated essentially westward on progressively younger formations. This is shown in Figure 2, where this axis, as mapped on the Pittsburgh coal, is shown cutting the depositional basin of the youngest known (Permian) consolidated sediments through its entire length. The northern part of this Permian basin, in the area southwest from Pittsburgh, has been variously referred to as the Appalachian geosyncline, and as the "Pittsburgh basin." That part of the Permian basin between the Burning Springs anticline and the city of Huntington, West Virginia, has been known as the Parkersburg syncline. Paul H. Price[4] describes this axis as follows.

> Extending southwest from New York it enters West Virginia at the southwestern corner of Pennsylvania and continues across the state to the west central part where its continuity is broken by the North-South Burning Springs anticline. From here it continues as the Parkersburg syncline to a point a few miles south of Huntington where it enters Kentucky.

In detail the so-called "Pittsburgh basin" is composed of several distinct synclines more or less *en échelon*, with low anticlines between. These anticlines are not shown on this map. Evidence of this structural effect is lost in the west-central part of the Permian basin, due to the masking influence of the north-south Burning Springs anticline. Immediately west of this anticline, the syncline is in evidence again, continuing under the name of the Parkersburg syncline, in a general southwest direction, and terminating against the west flank of the Cincinnati arch a short distance southwest of the Kentucky-West Virginia state line.

The north-south Parkersburg-Lorain syncline extends from the city of Lorain, Ohio, and passes east of Parkersburg, West Virginia,

[3] Paul H. Price, "The Appalachian Structural Front," *Jour. Geol.*, Vol. 39, No. 1 (January-February, 1931), p. 40.

[4] Paul H. Price and A. J. W. Headlee, "Physical and Chemical Properties of Natural Gas of West Virginia," *West Virginia Geol. Survey*, Vol. 9 (1937), p. 7.

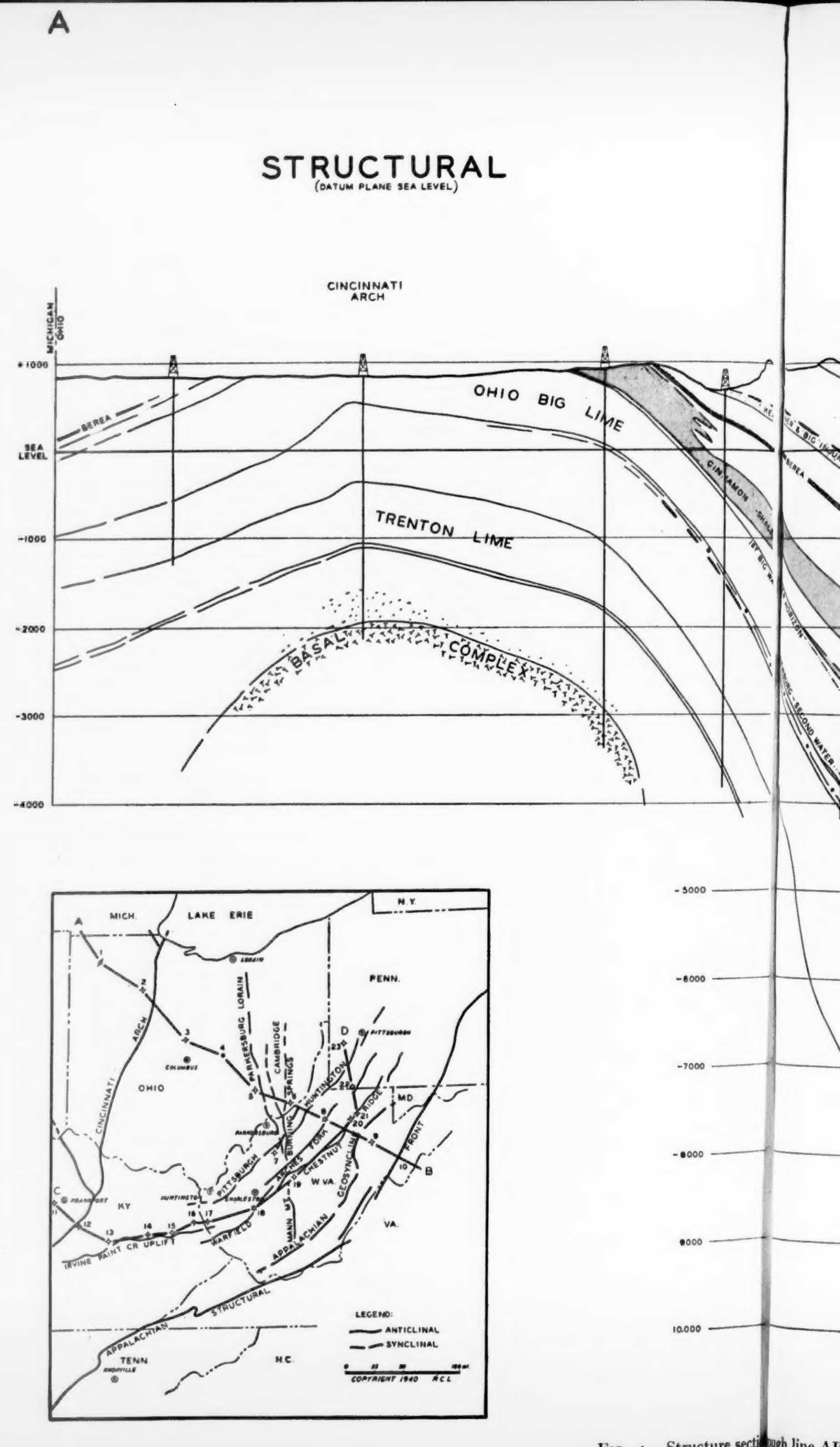
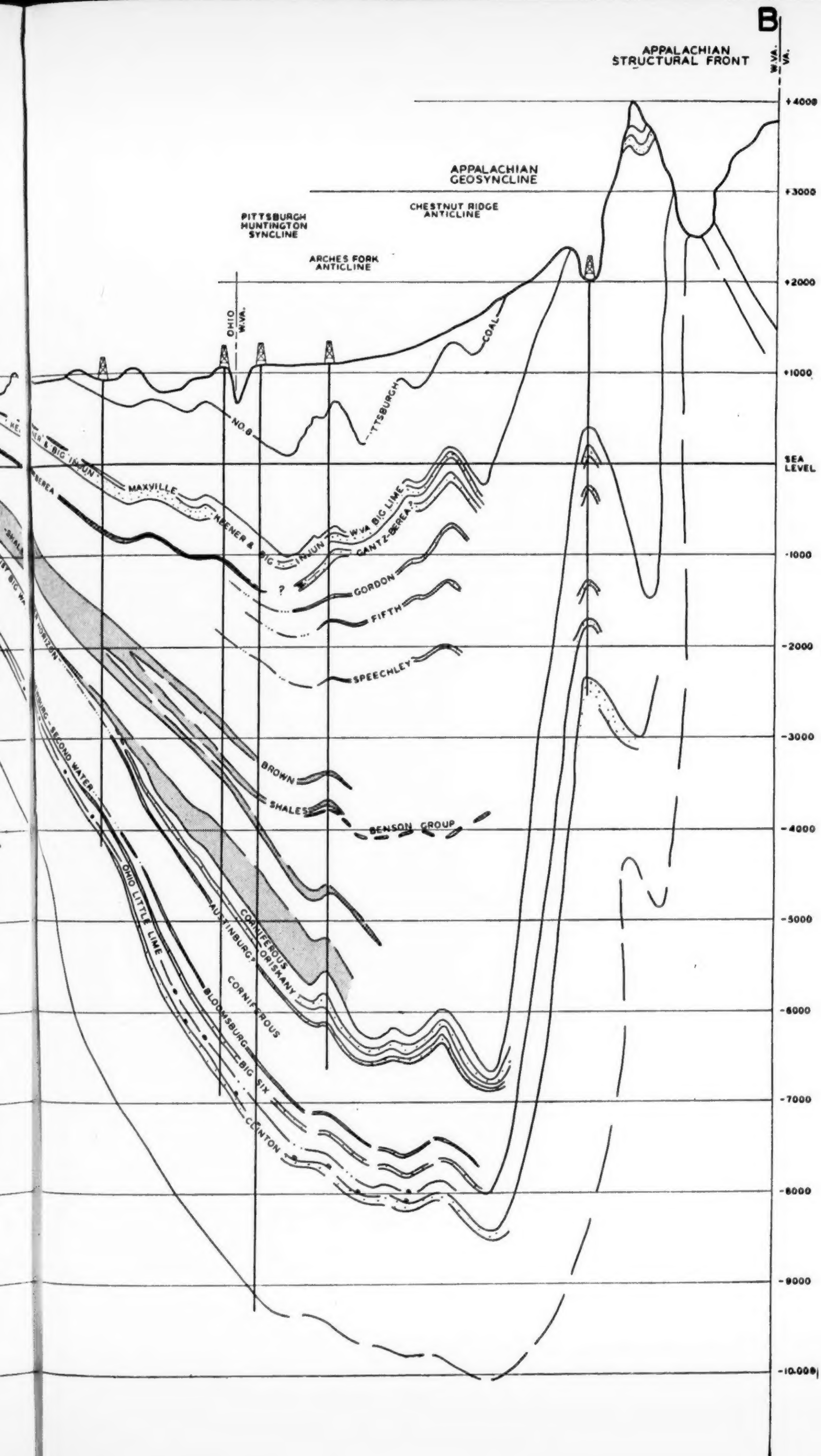
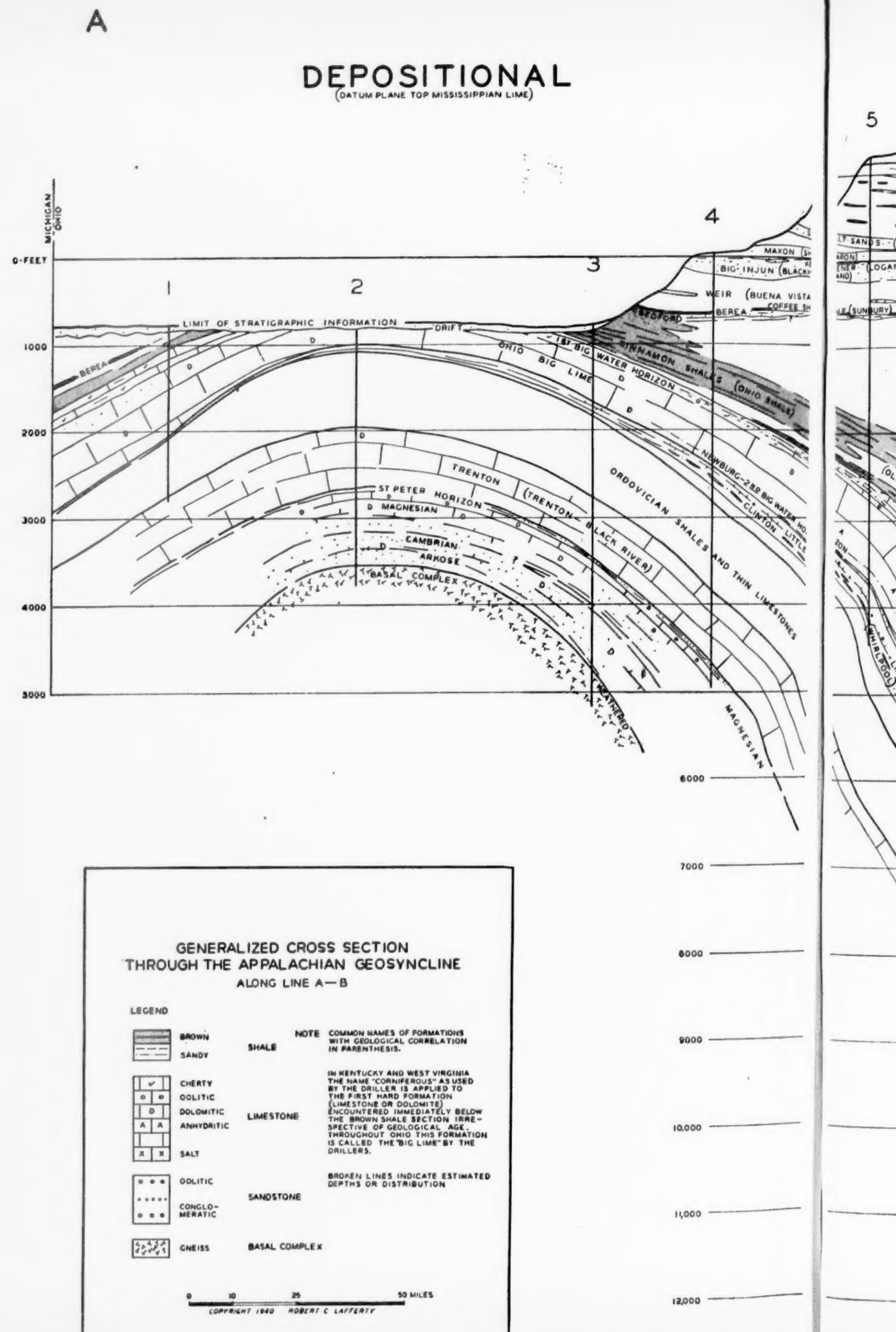


FIG. 4.—Structure secti ough line AB

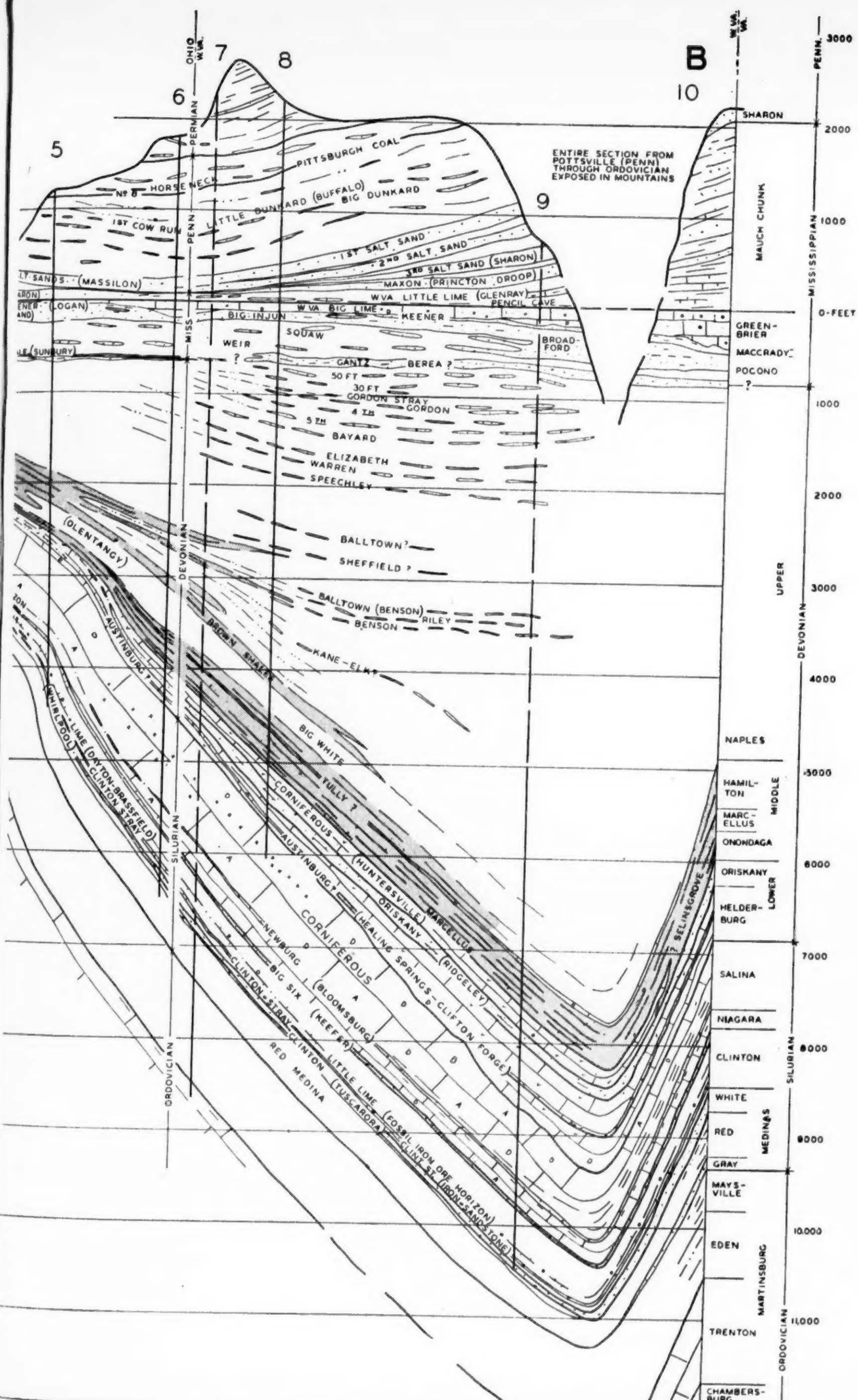


e secti ugh line AB of inset map.



A
DEPOSITIONAL
(DATUM PLANE TOP MISSISSIPPIAN LIME)
MICHIGAN
OHIO
0-FEET
1000
2000
3000
4000
5000
6000
7000
8000
9000
10,000
11,000
12,000
1
2
3
4
5
LIMIT OF STRATIGRAPHIC INFORMATION
DRIFT
BEREA
BEDFORD
1ST BIG WATER HORIZON
CINNAMON SHALES (OHIO SHALE)
OHIO BIG LIME
NEWBURG-2ND BIG WATER HO
CLINTON LITTLE
TRENTON
(TRENTON-BLACK RIVER)
ORDOVICIAN SHALES AND THIN LIMESTONES
ST PETER HORIZON
MAGNESIAN
CAMBRIAN
ARKOSE
BASAL COMPLEX
WEATHERED
MAGNESIAN
MAXON
BIG INJUN
WEIR (BUENA VISTA
BEREA
COFFEE SH
WHIRLPOOL
GENERALIZED CROSS SECTION
THROUGH THE APPALACHIAN GEOSYNCLINE
ALONG LINE A—B
LEGEND
BROWN
SANDY
SHALE
NOTE COMMON NAMES OF FORMATIONS WITH GEOLOGICAL CORRELATION IN PARENTHESIS.
CHERTY
OOLITIC
DOLOMITIC
ANHYDRITIC
SALT
LIMESTONE
IN KENTUCKY AND WEST VIRGINIA THE NAME "CORNIFEROUS" AS USED BY THE DRILLER IS APPLIED TO THE FIRST HARD FORMATION (LIMESTONE OR DOLOMITE) ENCOUNTERED IMMEDIATELY BELOW THE BROWN SHALE SECTION IRRESPECTIVE OF GEOLOGICAL AGE. THROUGHOUT OHIO THIS FORMATION IS CALLED THE "BIG LIME" BY THE DRILLERS.
OOLITIC
CONGLO-MERATIC
SANDSTONE
BROKEN LINES INDICATE ESTIMATED DEPTHS OR DISTRIBUTION
GNEISS
BASAL COMPLEX
0 10 25 50 MILES
COPYRIGHT 1940 ROBERT C LAFFERTY

Fig. 5


B
5
6
7
8
9
10
OHIO
W. VA.
W. VA.
VA.
PERMIAN
PENN
MISS
DEVONIAN
SILURIAN
ORDOVICIAN
SHARON
ENTIRE SECTION FROM POTTSVILLE (PENN) THROUGH ORDOVICIAN EXPOSED IN MOUNTAINS
PITTSBURGH COAL
Nº 8
HORSENECK
1ST COW RUN
LITTLE DUNKARD (BUFFALO)
BIG DUNKARD
1ST SALT SAND
2ND SALT SAND
3RD SALT SAND (SHARON)
MAXON (PRINCTON DROOP)
W VA LITTLE LIME (GLENRAY)
PENCIL CAVE
W VA BIG LIME
KEENER
BIG INJUN
SQUAW
WEIR
BROAD-FORD
(MASSILON)
(LOGAN)
(SUNBURY)
GANTZ
BEREA ?
50 FT
30 FT
GORDON STRAY
GORDON
4TH
5TH
BAYARD
ELIZABETH
WARREN
SPEECHLEY
BALLTOWN ?
SHEFFIELD ?
BALLTOWN (BENSON)
RILEY
BENSON
KANE-ELK
(OLENTANGY)
AUSTINBURG
BROWN SHALE
BIG WHITE
TULLY ?
CORNIFEROUS
(HUNTERSVILLE)
MARCELLUS
ORISKANY
(RIDGELEY)
AUSTINBURG
(HEALING SPRINGS-CLIFTON FORGE)
CORNIFEROUS
NEWBURG
(BLOOMSBURG)
BIG SIX
(KEEFER)
LITTLE LIME
(FOSSIL IRON ORE HORIZON)
CLINTON-STRAY
CLINTON
(TUSCARORA)
CLINT ST (IRON SANDSTONE)
RED MEDINA
LIME (DAYTON-BRASSFIELD)
(WHIRLPOOL)
CLINTON STRAY
SELINSGROVE
ST. PETER HORIZON ?
MAUCH CHUNK
GREEN-BRIER
MACCRADY
POCONO
NAPLES
HAMIL-TON
MARC-ELLUS
ONONDAGA
ORISKANY
HELDER-BURG
SALINA
NIAGARA
CLINTON
WHITE
RED
GRAY
MEDINAS
MAYS-VILLE
EDEN
MARTINSBURG
TRENTON
CHAMBERS-BURG (BLACK RIVER)
STONES RIVER
BEEKMAN-TOWN 2000-2300' DOLOMITE
ELBROOK (KNOX DOL.) 700-1000'
SCHIST
UPPER
MIDDLE
LOWER
PENN.
MISSISSIPPIAN
DEVONIAN
SILURIAN
ORDOVICIAN
CAMBRIAN
3000
2000
1000
0-FEET
1000
2000
3000
4000
5000
6000
7000
8000
9000
10,000
11,000
12,000

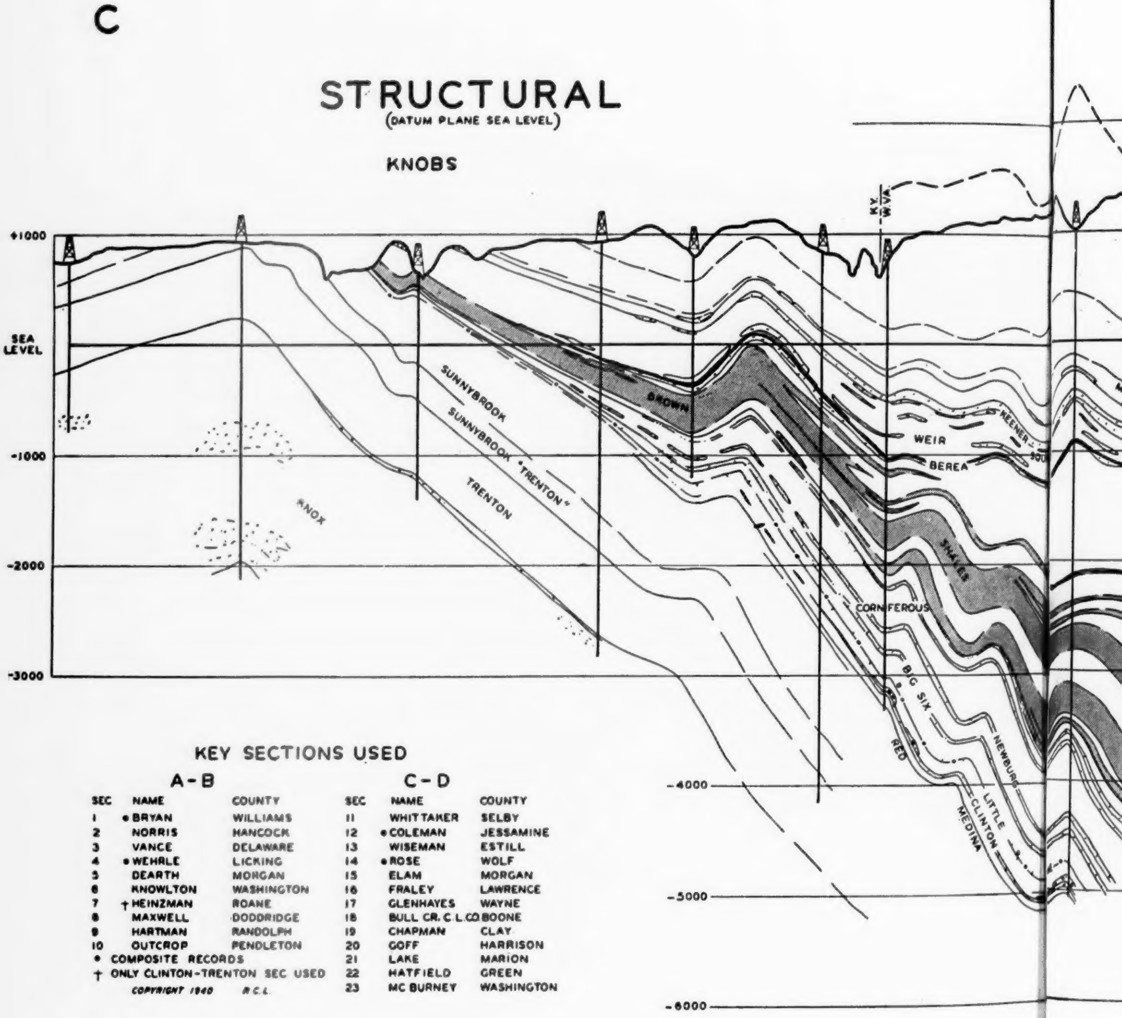
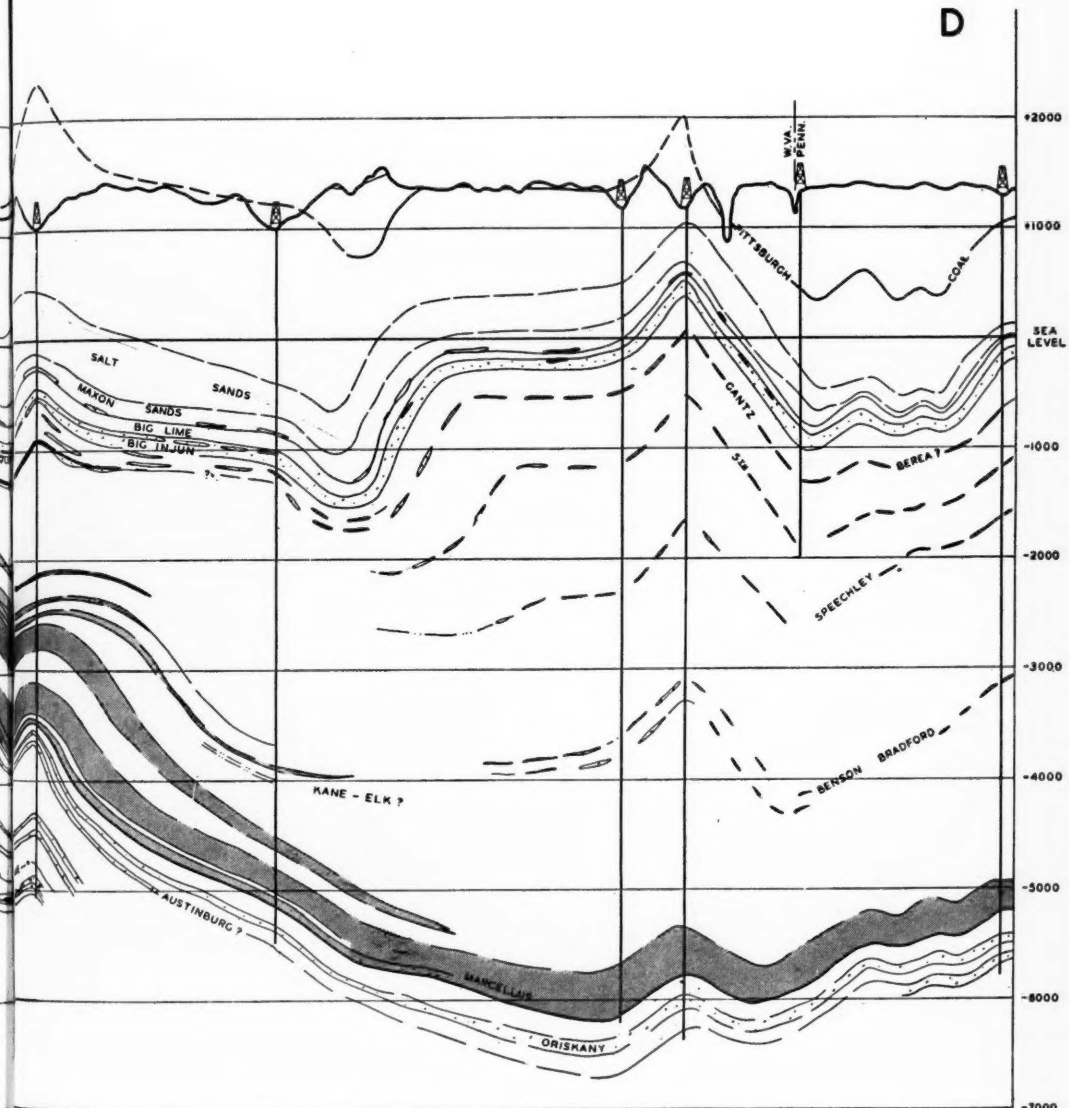

C
STRUCTURAL
(DATUM PLANE SEA LEVEL)
KNOBS
KY.
W.VA.
+1000
SEA LEVEL
-1000
-2000
-3000
-4000
-5000
-6000
-7000
SUNNYBROOK
SUNNYBROOK "TRENTON"
TRENTON
KNOX
BROWN
WEIR
BEREA
KEENER
SHALES
CORNIFEROUS
BIG SIX
RED
NEWBURG
LITTLE
CLINTON
MEDINA
KEY SECTIONS USED
A-B
SEC NAME COUNTY
1 • BRYAN WILLIAMS
2 NORRIS HANCOCK
3 VANCE DELAWARE
4 • WEHRLE LICKING
5 DEARTH MORGAN
6 KNOWLTON WASHINGTON
7 † HEINZMAN ROANE
8 MAXWELL DODDRIDGE
9 HARTMAN RANDOLPH
10 OUTCROP PENDLETON
• COMPOSITE RECORDS
† ONLY CLINTON-TRENTON SEC USED
COPYRIGHT 1940 R.C.L.
C-D
SEC NAME COUNTY
11 WHITTAKER SELBY
12 • COLEMAN JESSAMINE
13 WISEMAN ESTILL
14 • ROSE WOLF
15 ELAM MORGAN
16 FRALEY LAWRENCE
17 GLENHAYES WAYNE
18 BULL CR. C.L.CO. BOONE
19 CHAPMAN CLAY
20 GOFF HARRISON
21 LAKE MARION
22 HATFIELD GREEN
23 MC BURNEY WASHINGTON

FIG. 6


D
+2000
+1000
SEA LEVEL
-1000
-2000
-3000
-4000
-5000
-6000
-7000
W.VA.
PENN.
PITTSBURGH
COAL
SALT
SANDS
MAXON
SANDS
BIG LIME
BIG INJUN
GANTZ
5TH
BEREA ?
SPEECHLEY
BENSON
BRADFORD
KANE - ELK ?
AUSTINBURG ?
MARCELLUS
ORISKANY

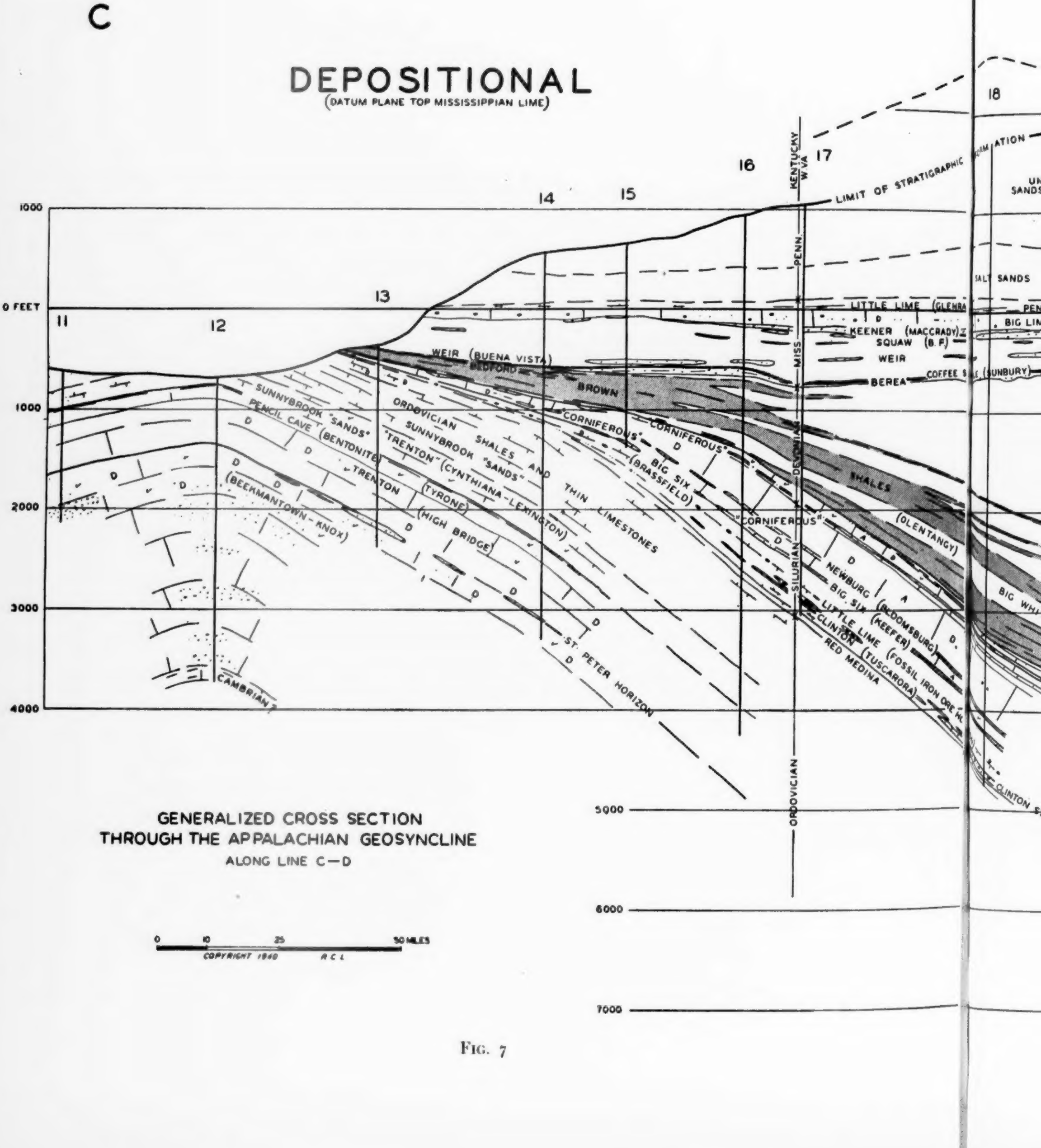
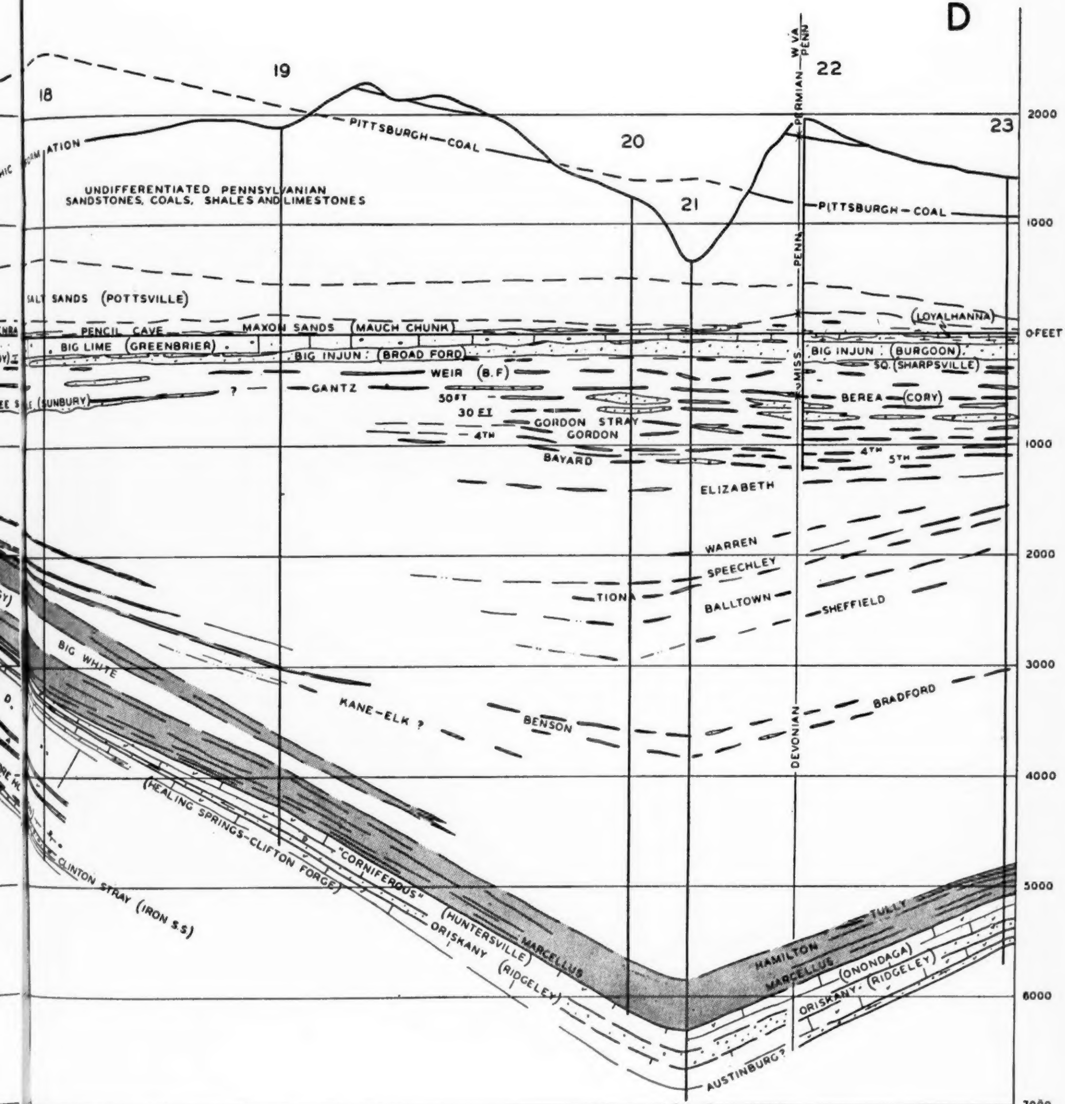

C
DEPOSITIONAL
(DATUM PLANE TOP MISSISSIPPIAN LIME)
GENERALIZED CROSS SECTION
THROUGH THE APPALACHIAN GEOSYNCLINE
ALONG LINE C—D
COPYRIGHT 1940
R.C.L.
0 FEET
1000
2000
3000
4000
5000
6000
7000
11
12
13
14
15
16
17
18
KENTUCKY
W.VA.
LIMIT OF STRATIGRAPHIC FORMATION
PENN.
MISS.
DEVONIAN
SILURIAN
ORDOVICIAN
SALT SANDS
LITTLE LIME
KEENER (MACCRADY)
SQUAW (B.F.)
WEIR
BEREA
COFFEE SHALE (SUNBURY)
WEIR (BUENA VISTA)
BEDFORD
BROWN
SHALES
CORNIFEROUS
(OLENTANGY)
BIG SIX
(BRASSFIELD)
NEWBURG
(BLOOMSBURG)
(KEEFER)
LITTLE LIME
(FOSSIL IRON ORE)
CLINTON
(TUSCARORA)
RED MEDINA
SUNNYBROOK "SANDS"
PENCIL CAVE (BENTONITE)
ORDOVICIAN SHALES AND THIN LIMESTONES
"TRENTON" (CYNTHIANA-LEXINGTON)
TRENTON (TYRONE)
(HIGH BRIDGE)
(BEEKMANTOWN-KNOX)
ST. PETER HORIZON
CAMBRIAN?

FIG. 7


D
18
19
20
21
22
23
W.VA.
PENN
PERMIAN
PITTSBURGH—COAL
UNDIFFERENTIATED PENNSYLVANIAN SANDSTONES, COALS, SHALES AND LIMESTONES
PENN.
SALT SANDS (POTTSVILLE)
PENCIL CAVE
MAXON SANDS (MAUCH CHUNK)
(LOYALHANNA)
BIG LIME (GREENBRIER)
BIG INJUN (BROAD FORD)
BIG INJUN (BURGOON)
SQ. (SHARPSVILLE)
WEIR (B.F)
GANTZ
50 FT
30 FT
GORDON STRAY
GORDON
4TH
BEREA (CORY)
MISS.
(SUNBURY)
BAYARD
4TH
5TH
ELIZABETH
WARREN
SPEECHLEY
TIONA
BALLTOWN
SHEFFIELD
BIG WHITE
KANE-ELK ?
BENSON
BRADFORD
DEVONIAN
(HEALING SPRINGS-CLIFTON FORGE)
CLINTON STRAY (IRON S.S)
"CORNIFEROUS" (HUNTERSVILLE)
ORISKANY (RIDGELEY)
MARCELLUS
HAMILTON
TULLY
MARCELLUS
(ONONDAGA)
ORISKANY (RIDGELEY)
AUSTINBURG?
2000
1000
0 FEET
1000
2000
3000
4000
5000
6000
7000

continuing in an essentially southern direction until it intersects the Arches Fork and Warfield anticlines. Evidence would indicate that this syncline, like the Man Mountain-Burning Springs anticline, is probably of later origin than the northeast-southwest trends. Due to the low dips and general flat terracing as revealed by the surface mapping in the area south of Parkersburg, many have confused the north-south trend with the northeast-southwest, and have connected the Parkersburg-Lorain with the Pittsburgh-Huntington syncline.

The writer is entirely in accord with Price about the location of the major synclinal axis as expressed in surface beds. However, the suggestion is made that the name Parkersburg, as applied to that synclinal area with northeast-southwest trend beginning just west of the Burning Springs anticline, and continuing southwest into Kentucky, be discarded and the name Huntington be substituted therefor, and that the axis of the Permian basin be known as the Pittsburgh-Huntington syncline.[5]

The Pennsylvanian sediments are found with maximum thickness southwest of the Permian basin in the vicinity of the Pine Mountain thrust fault in eastern Kentucky and Virginia.

Following Pennsylvanian deposition, the forces that were tilting and altering the old Appalachian basin expressed themselves from new directions as the focal point (shown by Permian deposition) was shifted laterally farther and was also rotated more than it was during any other period.

The Mississippian system reaches its maximum thickness in the area of the Appalachian structural front in southwestern West Virginia a considerable distance east of the Pennsylvanian basin.

Apparently during late Devonian or early Mississippian time other forces than subsidence became active in the Central basin as is evidenced by the first extensive lateral migration of basins in an essentially westward direction. Previous to this extensive lateral and rotational movement as expressed by the independent Permian, Pennsylvanian, and Mississippian basins, subsidence had been the major shaping force with only slight shifts in depositional axes to the east on older sediments resting on the basement complex.

[5] When the writer first proposed this nomenclature in a paper entitled "Structural and Depositional Cross Sections through the Appalachian Geosyncline" at the sixteenth meeting of the West Virginia Academy of Science held May 5, 1939, in Charleston, West Virginia, and at the first writing of this paper, he was not aware that the term Pittsburgh-Huntington had been previously used. Since that time in assembling the bibliography of this paper he has found previous use of this name in a paper by Sisler and Tucker appearing in *Geology of Natural Gas* (Amer. Assoc. Petrol. Geol., 1935), p. 993, although no explanation for the use of the name is given.

CROSS SECTIONS

Two cross sections have been constructed through this basin: one northwest and southeast across the deepest part of the basin, and another northeast and southwest roughly paralleling the strike of the basin.

CROSS SECTION AB (FIGS. 4 AND 5)

STRUCTURAL (FIG. 4)

The structural cross section is modelled somewhat after a cross section made several years ago by J. R. Lockett, of the Ohio Fuel Gas Company. Line *AB* was chosen as it traverses the deeper part of the basin and because deep wells (on some of which samples had been kept) on the general line were available. The northern end of this cross section was constructed from well records, and is partly based on a map prepared by Stout, Lamborne, Ring, Gillespie, and Lockett.[6] The extreme southern end (Section 10) is a generalized section taken from the West Virginia Geological Survey *Pendleton County Report*,[7] with some revisions suggested by Paul H. Price, and secured from a paper by Frank M. Swartz.[8] One well (Section 7) was projected to the general cross-section line, and the part of the well from the Clinton sand (Medina) to the Trenton was used, the upper part of the well being disregarded.

Only formations that are main markers are shown on this cross section and some of these are not carried the full extent of the section to the south, due to the distortion suffered near the Appalachian structural front. As these cross sections are primarily constructed for the petroleum geologist, and as there appears small likelihood of commercial oil or gas south of the Appalachian structural front in this area, the sections were terminated near this controlling feature.

In the lower left corner of this generalized cross section a small insert map shows some of the major geological features traversed by both sections *AB* and *CD*.

DEPOSITIONAL (FIG. 5)

This cross section is constructed along line *AB* from the same data used in the previous section. Numerous shallow wells were used in

[6] W. Stout, R. E. Lamborn, D. T. Ring, J. S. Gillespie, J. R. Lockett, "Natural Gas in Central and Eastern Ohio," *Geology of Natural Gas* (Amer. Assoc. Petrol. Geol., 1935), p. 899.

[7] William F. Prouty, John L. Tilton, P. H. Price, R. C. Tucker, *Pendleton County Report* (West Virginia Geol. Survey, 1927).

[8] Frank McKim Swartz, "The Helderberg Group of Parts of West Virginia and Virginia," *U. S. Geol. Survey Prof. Paper 158-C*.

these sections, but only the more important deep wells are indicated.

This section is constructed with the top of the Mississippian limestone (Greenbrier-Maxville) assumed as being horizontal. The top of the Mississippian limestone is in places difficult to recognize because of the presence of as many as five thin shales. Usually the base of the third "Pencil Cave" is taken as the top of the West Virginia "Big lime." This member of the Mississippian was chosen because it is the only shallow subsurface formation extending over the greater part of the area, that can be recognized definitely in well records. Also, a water string of casing is generally set near the top of the "West Virginia Big lime," affording more accurate measurements on the top of this formation than on some others which possibly could be used.

CROSS SECTION CD (FIGS. 6 AND 7)

This cross section was constructed for much the same reason as section *AB*. It follows in a general direction the strike of the basin. The western portion of this section was selected, passing over the highest point of the Cincinnati arch, and was constructed from well data furnished by D. J. Jones, State geologist, and associates in the Kentucky Department of Mines and Minerals.

STRATIGRAPHY

PERMIAN SYSTEM (DUNKARD SERIES)

The Permian system is composed of red and green soft shales, thin limestone beds, brown and gray sandstone, and some thin impure coal beds. Ray V. Hennen[9] gives a total thickness of 1,180 feet for the series as measured near Wileysville, Wetzel County, West Virginia, and remarks that it is probably the greatest thickness found in the state. In a generalized geologic column of West Virginia published in a recent volume,[10] an interval of 1,000–1,200 feet is given. Several more or less persistent sandstones are present, but no commercial oil or gas production, of which the writer has record, has been developed in this series. The base of this system is determined from fossil evidence to lie in the Cassville shale just above the Waynesburg coal.

PENNSYLVANIAN SYSTEM

This system produced a large percentage of the early oil and gas developed in the Appalachian area. Numerous lenticular sands are present, some of which are apparently continuous over fairly wide

[9] *Marshall, Tyler, Wetzel Counties Report* (West Virginia Geol. Survey, 1909), p. 106.

[10] "Physical and Chemical Properties of Natural Gas of West Virginia," *West Virginia Geol. Survey*, Vol. 9 (1937), p. 4.

areas while others reflect old stream channels. The greater amount of the production, from the various series above the Pottsville, is confined to the general area of the Huntington-Pittsburgh syncline, although scattered production is found in other areas.

Owing to the lack of dependable markers, as well as the poor logging of thin limestones and coals from drillers' correlations, considerable confusion is encountered in working with these shallow sands, and it is practically impossible to be positive of exact correlation over any considerable area. The most important and consistent marker of these series is the Pittsburgh, or No. 8, coal. In areas where this formation is present, depths to practically all sands are given with reference to it. Following, in descending order, are the drillers' names, as applied to these sands in West Virginia and Ohio, with their commonly accepted geologic correlatives in parenthesis.

MONONGAHELA SERIES
- Goose Run sand, Horseneck (Sewickley sandstone), Carroll (Uniontown)
- Pittsburgh, or No. 8, coal

CONEMAUGH SERIES
- Mitchell-Minshell (Connellsville sandstone)
- Murphy-Wolf Creek (Morgantown sandstone), Vincent sand
- Peeker-Moundsville (Saltsburg)
- First Cow Run-Little Dunkard (Buffalo), Buell Run (Buffalo)
- Big Dunkard-Macksburg 300-Foot (Mahoning)

ALLEGHENY SERIES
- Burning Springs sand (upper Freeport)
- Gas sand-Peeker (lower Freeport)
- Macksburg 500-Foot (Clarion)

POTTSVILLE SERIES

Little attention is given to the upper Pennsylvanian sands in this paper; however, the Pottsville series is so widespread and persistent that it deserves some attention.

Second Cow Run-Macksburg 800-Foot (*Homewood*).—This formation is the uppermost producing member of the Pottsville. It is fairly persistent in West Virginia, but is apparently very lenticular in Ohio, where it is locally known as the Macksburg 800, Macksburg stray, and Germantown sands.[11] This sand is ordinarily loosely cemented, medium-grained sandstone, containing gas, oil, or salt water. It, like the upper Pennsylvanian sands, conforms with structure as mapped on the Pittsburgh coal more closely than with that mapped on the underlying Mississippian.

Salt sands (*Pottsville series*).—"Salt sands" is a name used by drillers to identify a group of sands in the basal part of the Pennsylvanian and when used thus the name therefore does not refer to any particular sandstone member. In the northern portion of the basin three more or less definite members of the "Salt sand" group can be

[11] J. R. Lockett, assistant geologist, oral communication.

recognized and correlated with a fair degree of certainty, while in the southern end of the basin correlation is extremely hazardous. Near Charleston, West Virginia, as much as 450 feet of solid sand may be drilled without a shale break, while in wells a short distance away, three and in places four salt sands are logged in the equivalent interval.

First Salt sand.—This sand, present in both West Virginia and Ohio, contains oil and gas locally and consistently contains salt water. Considerable difficulty is commonly encountered in drilling, due to very fine sand being carried through the coarser and conglomeratic portions of the sand to the drill-hole by a strong flow of salt water. This condition is referred to by the drillers as "settling sand," because the sand packs around the tools if they are not in continuous motion.

Second Salt sand.—This sand, mainly present throughout West Virginia, is apparently absent or merges with the overlying "First Salt sand" in Ohio. It is normally much thinner than the "First Salt sand" and locally contains oil and gas and consistently contains strong salt brine.

Third Salt sand.—This last sand in the Pennsylvanian is much more lenticular than the upper two salt sands. J. R. Lockett[12] has suggested that the Maxton sand, as named near Sistersville, West Virginia, is also this sand. This can easily be true, as there was extensive erosion near the end of Mississippian time in the area of the Pittsburgh-Huntington syncline. The Maxon sand throughout West Virginia is usually considered as upper Mississippian in age and differs from the Third Salt sand in that it is less conglomeratic.

MISSISSIPPIAN SYSTEM

This system is probably the most important producing system in the Appalachian area. The West Virginia "Big lime" is the most easily recognized and dependable shallow subsurface marker present. Regional structure maps, constructed on the top of this formation, reflect the structure of the overlying Maxon as well as that of the underlying Pocono and Upper Devonian. Near the Appalachian structural front, this system is approximately 6,000 feet thick; northwestward toward the Cincinnati arch it thins in a short distance and the upper members become very lenticular.

MAUCH CHUNK SERIES

Maxton-Maxon (*Princeton-Droop?*).—The Maxton, or Maxon, sand is the first producing member of the Mississippian. It can gen-

[12] J. R. Lockett, oral communication.

erally be differentiated from the overlying salt sands due to intervening red shales coming immediately above. This lenticular sand varies from fine-grained to conglomeratic in character, but is ordinarily not as conglomeratic as the overlying salt sands. It contains oil, gas, and salt water. Proper sand conditions are of primary importance in oil and gas accumulation in this sand, with anticlinal structure of secondary importance. Normally, this sand is about 40 feet thick, but locally it may be replaced laterally in short distances by red shale. In Kentucky a second Maxon or "Bradley" sand is present in many places. Recently the Pittsburgh and West Virginia Gas Company[13] developed gas production in Braxton County, West Virginia, from what they tentatively correlate as the Webster Springs sand. This may represent the lower member of the Maxon as found in Kentucky.

West Virginia "Little lime" (Glenray).—Several thin gray to dark limestone layers are found above and between the Maxon sands and may represent the "Reynolds" limestone. Several lenticular limestones with a total average thickness of less than 50 feet, occur immediately below the Maxon. These limestones are generally dark in color and are referred to by the driller as the "Little lime." In many places they are shaly or sandy; where sandy the formation is referred to as "Blue Monday," due to its hardness. Commercial production of oil and gas is reported from the extremely lenticular "Blue Monday" sand in Gilmer County, West Virginia. This sand may be the new formation developed in Braxton County[14] and mentioned under the discussion of the Maxon. Possibly this horizon represents the Edray of the Mauch Chuck.

West Virginia "Pencil Cave" (Lillydale).—Normally at least one "Pencil Cave" is present as a marker, immediately above the West Virginia "Big lime." Where the top of the Greenbrier has suffered considerable erosion the Salt sands, or Maxon sand, may rest unconformably on the underlying "Big lime," cutting out the "Little lime" and "Pencil Cave." Where present, this bluish green to dark hard shale is given this name because it caves readily, commonly in the form of pencils. Normally, this shale is 3–5 feet in thickness, but in places it is 40 feet in thickness. As many as five "Pencil Caves" have been observed, within an interval of 50 feet between thin limestones.

As mentioned previously, where this condition exists, the third shale break is apparently the horizon that is most persistent and has been considered as marking the top of the "Big lime." Where the "Pencil Cave" is absent and a solid section of limestone is drilled, it

[13] John V. Goodman, assistant geologist, oral communication.

[14] *Idem.*

is customary to pick the top of the "Big lime" at the top of the first white limestone. Normally, 10–15 feet of dark shaly limestone is encountered above the white limestone. With such conditions, it is obviously impossible to determine definitely the top of the "Big lime" from drillers' logs. With care it is felt that this point can be correlated within 25 feet plus or minus. As most detailed structure maps are constructed with 25-foot contours, this error is far less important than the ever present doubt about the accurate correlation of any shallow sand present over as wide an area as is covered by the "Big lime."

GREENBRIER SERIES

West Virginia "Big lime" (Greenbrier-Maxville-Newman-Loyalhanna).—The West Virginia "Big lime" is an important producer of oil and gas in West Virginia, as well as being the most important shallow subsurface marker. Drilling is usually carried through the "Little lime" to a depth 5–25 feet below the "Pencil Cave." Here a water string of casing is set to shut off water encountered in the Salt sands or Maxon.

In Greenbrier County, West Virginia, from which locality this series was named, it is 700 feet in thickness.[15] Under cover through the producing fields in the basin, a thickness of 50–250 feet is encountered. Farther northwest in Ohio and Pennsylvania near the axis of the Pittsburgh-Huntington syncline, it is thin and disappears in a short distance north and west of this point. In Ohio this series is known as the Maxville. Stout[16] holds the opinion that this series is probably composed of the Gasper and Fredonia (Chester), and is possibly the correlative of the Union member of the West Virginia Greenbrier. Butts[17] has shown that the Chester, Ste. Genevieve, and St. Louis members thin from west to east across the Cincinnati arch, and that only the Chester and part of the Ste. Genevieve are present in the northern portion of eastern Kentucky. Evidently the lower Mississippian limestones cross the arch in southern Kentucky in the vicinity of the Pine Mountain basin (Pennsylvanian) and join the thick Mississippian limestone basin in southern West Virginia. The West Virginia Geological Survey, in its reports, both on Greenbrier County and on the limestones of West Virginia, thoroughly discusses these correlations. Lucke,[18] in a south-north cross section along the Mississippian

[15] *Greenbrier County Report* (West Virginia Geol. Survey, 1939), p. 252.

[16] Wilbur Stout, State geologist of Ohio, oral communication.

[17] Charles Butts, "Mississippian Series of Eastern Kentucky," *Kentucky Geol. Survey*, Ser. VI (1922). Cross section in Appendix.

[18] "Limestones of West Virginia," *West Virginia Geol. Survey*, Vol. 12, p. 44.

outcrop in West Virginia, shows that there is more thinning and pinching-out of members from the lower part of the formation than from the top or middle. The writer has had opportunity to examine a few samples, most of which are from the southern part of West Virginia, but is in full agreement with Martens[19] that the Greenbrier is so variable that with the few samples available it is impossible to be sure of any definite correlations. Apparently the Union member (Chester) under cover, as well as at the outcrop, is the most persistent member. It is very probable that the dark, upper shaly Alderson member is often correlated as the "Little lime" where the "Pencil Cave" is absent.

Examination of well samples in southern West Virginia shows the Greenbrier to consist of white, tan, and brown crystalline limestone with some tan to greenish sugary dolomite near the base. Lenses of clear angular to subangular sand, ranging in size from 0.25–0.6 millimeter, are commonly found in the middle section (Bethel?). One to three oölitic zones are present. In places these tan limestone oölites exhibit concentric growth, in other places they are apparently solid limestone. Few of them are more than 0.5 millimeter in diameter. Most production from the "Big lime" is confined to areas near the crests of anticlines, although local structure apparently is of minor importance. Gas and some oil are produced from oölitic zones, where the oölites are loosely cemented, or from fracture zones. Probably the largest production is in fracture reservoirs. Some connate water is present in restricted areas, but if serious water conditions exist, they can generally be traced to migrating water from overlying formations through improperly abandoned wells. The "Big lime" responds satisfactorily to acidation.

MACCRADY SERIES

Due to lack of samples, as well as to the inaccuracies of drillers' naming, considerable disagreement exists among geologists concerning the proper correlation of the Keener sand. Some consider the Keener as a sandy phase of the "Big lime"; others feel that it is a lens of the upper part of the Big Injun sand; while others believe it is Maccrady in age. Samples will help to answer this question.

The thickness of the Maccrady series in Smyth County, Virginia, is in excess of 700 feet,[20] but it thins in a short distance toward the Cincinnati arch. On the outcrop in southern West Virginia it is re-

[19] James H. C. Martens, "Petrography and Correlation of Deep Wells," *West Virginia Geol. Survey*, Vol. 9 (1939), p. 19.

[20] George W. Stose, "Gypsum Deposits of the United States," *U. S. Geol. Survey Bull. 697* (1920) pp. 283–98.

ported as having a thickness ranging from 25 to 350 feet,[21] and consists of red and purple shales. Under cover this series contains an important lenticular sand member known as the Keener.

Keener (Logan).—This sand may be separated from the overlying "Big lime" by red micaceous shale ranging from a few inches to 20 feet in thickness, or by dark gray or greenish siliceous shale. As there are red shales in the Greenbrier limestone on the outcrop, and as the top member of the underlying Broad Ford sandstone on the outcrop is reddish brown, it is rather difficult from the lithologic character of the outcrop to decide whether or not the Keener is of Maccrady age. The Keener, where productive, is a medium- to fine-grained, white to clear sandstone. In places the sandstone has a reddish cast and contains considerable coarse sand. Smoky chert and pyrite are commonly found in the lower part of the sand. In this paper the so-called "Red Injun" of eastern Kentucky and southern West Virginia is considered as Maccrady in age. It is impossible to decide whether or not this sand is the Keener of northern West Virginia without more sample information; however, the common presence of red shale above the sand in places indicates the validity of this correlation. The sand is extremely lenticular, having a thickness of 20–40 feet in one well, while in an offset well, the interval is occupied by red shale with only a few feet of dolomite and silica-cemented sandstone. This formation has had spectacular, as well as long-lived production, due partly to the lenticular and other varied nature of the sand in producing fields. Passing from West Virginia into Ohio this sand is water-bearing, a condition that is observed in few places in West Virginia. In Ohio it is identified as Logan or upper Waverly. Where water-bearing, production is anticlinal;[22] otherwise production is controlled by sand conditions.

POCONO SERIES

Big Injun sand (Broad Ford—Blackhand-Burgoon).—The Big Injun is probably the most widespread shallow sand in the Appalachian area. On the outcrop the upper part is commonly brownish in color and the entire section may be thin-bedded, with numerous shale partings. Under cover this condition seemingly does not exist to the extent that it does on the surface, but a few black shale partings are encountered, and in some areas the sand is present as only a "shell." This sand is separated from the overlying Keener by black micaceous shale ranging from a few inches to 30 feet in thickness, or in places by

[21] *Mercer, Monroe, and Summers Counties* (West Virginia Geol. Survey, 1926), p. 493.

[22] J. R. Lockett, oral communication.

red shale. In parts of southern West Virginia and eastern Kentucky, the drillers log "Red" and "Gray Injun." The writer considers this so-called "Red Injun," or at least a part of it, as Maccrady and the underlying gray sand, or "shell," as true Big Injun.

The Big Injun is clear to frosted, angular to sub-round, fine- to coarse-grained sandstone with a white to bluish tint in hand-specimens. In places conglomeratic zones are encountered, but belong to no definite horizon. Pyrite and smoky chert are commonly found in the lower part of the sand.

The Big Injun in Ohio and parts of West Virginia contains water and in these areas production is confined to anticlincal structure. In other areas it produces oil and gas both on anticlines and in synclines.

Squaw sand (*Broad Ford-Sharpsville*).—The Squaw sand, below the Big Injun, exhibits essentially the same sand structure. It is extremely lenticular and is generally logged as a "shell." Due to its lenticular and water-free nature, sand conditions being favorable, it produces with no apparent relationship to structure. In places it merges with the overlying Big Injun and is logged in one unit as this upper sand.

Weir sand (*Broad Ford-Buena Vista*).—The Weir sand yields some of the longest-lived and largest production in the Appalachian area. It is normally very fine-grained, white sandstone, but may have some scattered conglomeratic layers. On the outcrop it is ordinarily evenly bedded with here and there black shale partings, a condition that exists in productive fields. This sand is commonly represented by a "shell," but where present is fairly consistent. As very little water is present in this formation proper sand conditions are of primary importance, although most of the production found is located high on the flanks of anticlines.

Coffee shale (*Sunbury*).—The "Coffee shale" of the driller is one of the most important shallow subsurface markers in the western and southern part of the basin. Occurring immediately above the Berea sandstone, this dark brown fissile shale is present in all areas where the sand can be identified as the true Berea. In the extreme southern part of the basin where this sand is absent, the "Coffee shale" is considered to have merged with the underlying Devonian brown shale to form the Chattanooga shale. It is present in eastern Kentucky, southern West Virginia, and southeastern Ohio, but is rather indefinite in the extreme eastern and southeastern parts of Ohio. This condition is apparently true in north and northeastern West Virginia as it has not been definitely identified on the outcrop. In these areas, where the writer has had an opportunity to examine well samples, it has not been possible to identify it as such.

Berea sand (*Berea-Cory*).—The Berea of the driller, and the Berea of outcrop at its type locality, are the same in areas where it can be identified with some degree of certainty. In the southern part of the basin the Berea is fine- to medium-grained sub-angular to angular, white to clear, well sorted sandstone. In places, it is very coarse-grained and has conglomeratic lenses. In many places a black shale, varying from 5 to 20 feet in thickness, is present near the middle of this sand, separating it into two members. These are generally referred to as the First and Second Berea, although in places local names are used for the lower sand body. The Second Berea is considered by some as the equivalent of the underlying Bedford formation; however, as the Bedford is characteristically blue or red, this correlation is of doubtful validity. In central West Virginia, where the Berea can be differentiated with certainty from the underlying Devonian sands, it is apparently extremely lenticular, spreading over a vertical interval of 100 feet. In these areas this horizon may be represented by one continuous sand body in one well while in wells a short distance away either the First or Second Berea, or both, may be encountered with the equivalent interval occupied by either a "shell" or shale.

Although recent coring in one large southern West Virginia Berea oil field has indicated that 11–31 per cent of the available pore space is filled with connate water, little, if any, water is produced with the oil. This condition is almost universal south of the axis of the Pittsburgh-Huntington syncline, and production is a matter of favorable sand conditions. North of the Pittsburgh-Huntington syncline the Berea contains water, and production is normally anticlinal.

In areas where the overlying Sunbury shale can not be recognized and where the underlying Devonian contains numerous sands, positive identification of the Berea is hazardous, if not impossible; therefore, it is a poor regional marker. From scattered work in these areas it appears entirely plausible that the true Berea (basal Mississippian) has either disappeared or is occupying the upper part of a transition or reworked zone. The writer had occasion to examine samples, starting near the middle of the Big Injun and continuing to the total depth of the well shown in Figure 7, Sec. 22. In none of the samples examined was there any suggestion of Sunbury shale, and it is doubted very much if the Berea can be identified without this marker. From 2,565 to 2,578 feet very fine-grained, slightly micaceous sand was noted. This was typical of the "Broad Ford" sands as present in this well, with the exception that some of the grains had a reddish cast. From 2,578 to 2,616 feet the interval is occupied by dark gray, fine-grained, slightly micaceous and siliceous shale. From 2,616 to 2,666 feet a sand

varying from fine-grained to large, angular, clear to smoky, quartz fragments is present. The sand from 2,616 to 2,666 feet is more representative of the Devonian sands as observed in this well than the sand from 2,565 to 2,578 feet and it is considered that the Mississippian-Devonian contact is probably in this latter sand.

DEVONIAN SYSTEM

The interval between the basal Mississippian and the top of the "Corniferous limestone" (Middle Devonian) is occupied by shales of varying colors, sands, and some thin limestones. The various State surveys have divided these rocks into series. The series can be recognized in a general way from well records, but the placement of definite contacts, without more sample information than is now available, is practically impossible. For this reason, it is thought advisable to use only the major divisions of the Devonian.

UPPER DEVONIAN

Correlation of Upper Devonian sands from drillers' records is apparently more a matter of correlating names than sands. These sands are very lenticular and it appears that the names are applied to any sand encountered within a definite depth below some shallow marker. Names given to producing sands in limited areas can possibly be considered as correct, but where these names are applied to sands in other regions correlation is doubtful.

Gantz sand.—The name Gantz is in widespread usage and is usually applied to what is considered the upper part of the Hundred-Foot sand of Pennsylvania. As mentioned previously in connection with the discussion of the Berea, the lower part of a possible transition zone is regarded as being occupied by this sand. A type plotted record in the area of Sections 20, 21, 22 (Fig. 7) indicates that the Berea-Gantz occupies a vertical section of more than 100 feet, with one to three sand lenses in this interval, one or all of which may be present.

Fifty-Foot sand.—The Fifty-Foot sand is the first sand member that is definitely in the Hampshire ("Catskill"). Where examined it varies from fine to medium well sorted sand to angular to rounded fine-grained to large-grained, poorly sorted sand. Ordinarily, red shale separates it from the underlying Thirty-Foot sand, but this interval may consist of dark gray, fine-grained shale. As this sand ordinarily contains water, anticlinal or lens structure is necessary for production.

Thirty-Foot sand.—This sand exhibits essentially the same grain structure as the Fifty-Foot; however, it does not appear to be as wide-

spread. In places it is separated from the overlying Fifty-Foot sand by red shale, at other places by gray sandy shale.

Gordon Stray and Gordon.—These lenticular sands in places merge; in other places they are separate and distinct. Apparently, they mark one of the most persistent horizons of the Hampshire. They vary from fine- to medium-grained white sand, to large, angular to rounded, clear, smoky or rose quartz fragments. These sands are ordinarily separated by red shale. Proper sand conditions appear more vital to production than anticlinal structure. Local anticlinal structure, mapped on this sand, compares favorably with structure as reflected on the overlying "Big lime."

Fourth sand.—The Fourth sand is very similar to the Gordon sands, but is much more lenticular. It is separated from the Gordon above by red shale and from the Fifth below by red shale. This lower red shale appears to be near the base of the Hampshire in West Virginia, as it is generally the last red shale logged. Farther north in Pennsylvania the red shale continues to the Elizabeth horizon.

Fifth sand.—The Fifth sand is lithogically similar to the foregoing sands, but apparently is not as lenticular as the Fourth sand. It, like the Gordon and Fourth, depends more on sand conditions for production than on anticlinal structure.

Bayard or Sixth sand.—In attempting to carry interval name correlation from Pennsylvania into northern West Virginia, it is very possible that type sands in Pennsylvania and interval sands in West Virginia are not the same. In Pennsylvania both the Bayard and the Elizabeth are in the "Pink rock" zone. In West Virginia, where samples were examined, the Bayard is fine- to large-grained, white to brown sand and apparently belongs in the Chemung formation. Like the Hampshire sands it is more dependent on sand conditions than on anticlinal structure.

Elizabeth or Seventh sand; Warren; Speechley; Balltown; Sheffield.—The writer has had no opportunity to examine any of these sands from wells in West Virginia, but in Pennsylvania where examined, they are very similar to the Bayard as already described. The Speechley apparently is the most persistent of this group and may be one of the new oil-producing formations recently developed in north-central West Virginia.

Balltown, Riley, Benson (Benson group).—These sands have been correlated with the Bradford sands of Pennsylvania. An unsuccessful attempt has been made to correlate, and contour on, these sands in considerable areas. As they are water-free, proper sand conditions are more essential to gas production than is structure. These sands, al-

though having small open flows, have rock pressures of approximately 1,900 pounds. They can best be considered as a group, or lenses of the same sand body and should more properly be referred to as the First, Second and Third Benson, in the same manner as the Chemung sand groups of Pennsylvania.

Kane-Elk?—In several deep wells, sands have been logged below the Benson group. These sands may be correlated with the Kane or Elk groups of sand as found in Pennsylvania. To date, these sands have not produced in West Virginia.

In the direction of the arch, these Upper Devonian sand bodies lose their identity in a short distance and are represented as thin sand lentils, or siliceous shales, with interfingering brown bituminous shales in the lower limits of the series.

Brown shales.—Several more or less persistent "Brown shale" members are present in the "Shale gas-producing area" of Kentucky, West Virginia, and Ohio. This production is confined to the general area between Huntington, West Virginia, and Pikeville, Kentucky, and roughly parallels the lower margin of the epi-continental shelf as indicated by Figures 1, 5 and 7. A detailed map of these shale gas fields is published with the *Oriskany Sand Symposium.*[23] West from this area these various "Brown shale" members merge to become the brown-black, friable Ohio shale.

In the shale gas-producing area of eastern Kentucky, Hunter and Munyon[24] have prepared several analyses, of which the following is typical.

	Percentage
Quartz	49.78
Bituminous material	36.75
Pyrite	13.47
	100.00
Kerogen	3.36

The quartz in the "Brown shale" is apparently chemically precipitated as it is very angular, as well as having a short and a long axis; the long axis is scarcely more than 0.05 millimeter in length and grades from this maximum size to invisibility.

As far as can be determined, the quartz percentage of a shale section has small relationship to the gas production. Where samples were secured from wells with varying rates of open flow, the percentage of pyrite appears higher in the large open-flow wells than in the wells of

[23] *Oriskany Sand Symposium* (Appalachian Geol. Soc., 1937), map in pocket.

[24] C. D. Hunter and A. C. Munyon, "Black Shales," *Devonian Shales Symposium* (Appalachian Geol. Soc., 1935), paper No. 2, analysis No. 3.

smaller volume. This is very suggestive of a fracture-type reservoir. Wells producing from this formation are apparently dependent on fracture systems created in the shale in a vertical plane as well as horizontal openings of the laminae in the shale. Most of the larger wells are near the crests of anticlinal structures, although a high percentage of good wells is found on the flanks and in the synclines. Regional fracture zones are probably more dependent on the hinge line created by differential settling along the lower margin of the epicontinental shelf than on other causes.

East of this shale-gas area and south and southwest of Charleston, West Virginia, shale gas has been developed that has a slightly different type section, as well as reservoir. The "Brown shale" is present in several more or less persistent members interfingering with bluish gray, siliceous, or sandy shales. No analyses are known to have been made of these "Brown shales," but probably the kerogen is much lower. The silica content is possibly about the same, but is present as very fine angular sand with a maximum axis length of 0.1 millimeter. Gas in this section is encountered in both the gray and the "Brown shales." From the numerous small "pays" encountered it is very suggestive of thin sand lenses. Shale wells are shot with several thousand pounds of gelatin or detonite over the entire section where gas showings are logged.

Big White (*Olentangy*).—Separating the gas-bearing Brown shales from the underlying Naples (Genesee?) Hamilton-Marcellus shales, is gray soft to siliceous shale, called by the drillers the "Big White." This shale crops out near Columbus, Ohio, and is found as a distinct facies as far south as Irvine, Kentucky. Farther south along the outcrop the facies could very easily be confused with the Crab Orchard (Clinton) shale, as the intervening Devonian and Upper Silurian rocks are missing. Under cover and farther into the basin, this formation thickens within a short distance and may be one of the most important markers in the Devonian. This shale is recognized in well logs deep in the basin, but in the writer's knowledge has never been identified as such on the western outcrop of the Devonian.

Tully limestone?—Near or at the base of the Upper Devonian, A. Y. Barney,[25] in his examination of the Lewis Maxwell well (Fig. 5, section 8), has tentatively identified a thin dolomitic limestone that may represent the Tully of the Pennsylvania and New York section. A brown dolomitic limestone has been noted in several deep wells at this location, but is not definite as a horizon, as it is in New York and Pennsylvania.

[25] A. Y. Barney, unpublished paper delivered at Morgantown meeting of the Appalachian Geological Society, March 13, 1939.

MIDDLE DEVONIAN

The Middle Devonian, as well as the lower part of the Upper Devonian in this area, is composed of blackish brown, carbonaceous shales, light to dark gray, siliceous shales, and some thin limestones in the upper part, with the calcareous cherty "Corniferous" occupying the lower measures. These shales thin northwest toward the Cincinnati arch and are more conformable with structure as mapped on the underlying "Corniferous" than on overlying horizons.

Hamilton-Marcellus shale.—Immediately overlying the "Corniferous" limestone in West Virginia, southeastern Ohio, and sporadically in eastern Kentucky, is found the characteristically dark, brownish black, fissile Hamilton-Marcellus shale. On the outcrop in southeastern West Virginia, a thin limestone is found near the middle of this formation. This limestone, named Selinsgrove by Roger, has both Marcellus and Onondaga fossils as has the underlying shale separating it from the Ridgeley (Oriskany). Whether this limestone merges with the Huntersville to form the "Corniferous" of the driller, or represents the total thickness of Huntersville on the outcrop in this county (Fig. 5, section 10) is not definitely agreed upon. This shale is much darker than the overlying "Brown shales" and has produced commercially in only a few isolated places, in the writer's knowledge. However, frequent showings of gas are logged and "blow-outs" in wildcat wells drilled in the deeper part of the basin are commonly encountered.

"Corniferous" and Ohio "Big lime."—In Kentucky and West Virginia the name "Corniferous," as used by the driller, is applied to the first hard formation, limestone or dolomite, encountered immediately below the "Brown shale" section, irrespective of geological age. Throughout Ohio this formation is called the "Big lime" by the drillers. Toward the Cincinnati arch this thick limestone section thins and many members disappear. Near Irvine, Kentucky, on its western outcrop, the entire section has thinned to less than 25 feet and is identified as the Boyles limestone (Hamilton-Onondaga). Several miles east of the outcrop this limestone is absent,[26] with the overlying Brown shale resting unconformably upon the Silurian. This condition may be duplicated at Columbus, Ohio, in the Devonian-Silurian rocks.

Onondaga-Huntersville.—In wells located in southeastern Ohio, northern Pennsylvania, and West Virginia where samples of the Middle Devonian limestones have been examined, the upper part consists of gray, brown, or dark crystalline limestone followed by light tan to

[26] Arthur C. McFarlan, "Unexposed Silurian Section and Producing Zone of the Irvine Oil Field, Estill County, Kentucky, *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 22, No. 10 (October, 1938), p. 1448.

smoky chert that appears as replacement and lower chert that has the appearance of being bedded. Midway between the top of this limestone section and the underlying Oriskany, a sandy zone is commonly found. Glauconite zones are also present and some dolomite. Gas and showings of oil are commonly logged near this point. Martens considers production from the Summit[27] gas pool, Fayette County, Pennsylvania, as coming from porous shattered zones in this calcareous chert. This chert section, where examined from well samples, is essentially constant and can be readily recognized.

The Devonian "Brown shale" overlap, so conspicuous in Kentucky and Tennessee, apparently began early in the Middle Devonian, and probably was eroded before the Devonian "Brown shales," lying *above* the "Big white," were deposited. This is evidenced by the erratic remnants of the Boyles limestone (Hamilton-Onondaga), which, although present on the outcrop near Irvine, Kentucky, is absent from well samples a few miles east of the outcrop under cover. This condition may likewise be present near Columbus, Ohio, since at some point between sections 5 and 6 (Fig. 5) the Onondaga disappears. From here to the outcrop near Columbus, Ohio, the writer has had no opportunity to study well samples, but has observed both the Delaware and Columbus in the field.[28] The Delaware varies from a coarse, blue crystalline limestone near the top to brown, fine-grained limestone near the base, and the entire section is composed of thin layers of limestone, chert, and dark brown shale. Stauffer[29] correlates the Delaware as of Hamilton-Onondaga age; this being true, the Hamilton-Marcellus shale at some point between section 5 and outcrop, must merge with the Delaware, and the underlying Columbus has either suffered considerable erosion east of the outcrop or is of much lower Devonian age than it has been considered.

LOWER DEVONIAN

The Lower Devonian is divided into two divisions, the Oriskany and the Helderberg.

Until very recently the Huntersville and Shriver cherts were considered as being of Oriskany age, but Price and Woodward in a recent

[27] James H. C. Martens, "Summit Gas Pool of Southwestern Pennsylvania," unpublished paper delivered at Morgantown meeting of Appalachian Geological Society, March 13, 1939.

[28] Geology N. 204, Ohio Wesleyan University, 1926, under Professor Lewis G. Westgate.

[29] G. D. Hubbard, C. R. Stauffer, J. A. Bownocker, C. S. Prosser, and E. R. Cumings, "Columbus, Ohio," *U. S. Geol. Survey Atlas Folio 197* (1915), pp. 45-46.

paper[30] have revised these, as well as other Devonian correlations. The Oriskany as considered in this paper is composed of only one member, the Ridgeley, while the Helderberg is composed of limestone, cherty limestone, and two more or less persistent quartzitic sands. From well samples it is difficult to differentiate the various cherts without knowing their relationship in the section. The contact between the Devonian and the underlying Silurian, from well samples, is picked at the top of the main dolomite-anhydrite zone.

Oriskany (*Ridgeley*).—The Oriskany is clear glassy-appearing angular to sub-round sandstone, varying in size from extremely fine- to coarse-grained sand. Near the middle of the sandstone an extremely calcareous shale or limestone parting is found in many places. Some geologists refer to the section above this break as zone A, and below as zone B. This sandstone is thickest on the southeastern side of the basin, gradually thinning until it disappears well up on the flank of the Cincinnati arch. Near this western disappearance the sand is much finer-grained and more quartzitic than in the producing areas. The Oriskany horizon, as such, is not recognized on the outcrop near Columbus, but is considered as being unconformably present at the base of the Columbus limestone. Examination of well samples east of the outcrop will help determine whether the thin sandstone, found here and there, is the Oriskany or one of the lower Helderberg sands. Anticlinal structure has been vitally important in controlling accumulation in the Oriskany gas fields of New York and Pennsylvania, but to date, in Ohio and West Virginia has been of secondary importance with proper sand conditions as the controlling factor.

All of the gas fields found in West Virginia and Ohio roughly parallel the western limits of this sand, and lie between this sand limit and a so-called "perched" water table closely associated (Fig. 3) with the gas belt on the east. Commercial oil is found downdip associated with gas in Ohio, but has not been found, to date, in West Virginia.

HELDERBERG SERIES

The Helderberg is recognized as being the basal member of the Lower Devonian rock in West Virginia and is probably the equivalent at least in part of the Detroit River series in northern Ohio.

Two quartzitic sands are present in this series on the outcrop in West Virginia, under cover; and northwest toward the Cincinnati arch, they are found in all wells where samples were examined. Either

[30] Paul H. Price and Herbert P. Woodward, "Résumé of the Devonian System of West Virginia," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 24, No. 11 (November, 1940), pp. 1983–94.

or both of these lenticular sands may be present, but at places are so mixed with limestone and chert that they represent a horizon more than a true sandstone. Where examined in southeastern Ohio and near the Kentucky-West Virginia border they have lost their extremely quartzitic nature and are very similar to the Oriskany.

These two members, the Healing Springs and Clifton Forge,[31] comprise what is considered in this paper as the Austinburg sand or first "Big lime" water horizon of Ohio.

The greater portion of the Helderberg is composed of brown to white crystalline limestone or smoky tan or dark brown calcareous cherts and at places brown, silty shale. On the outcrop in West Virginia these various rocks are recognized as separate members, but from well cuttings it is doubtful if the various limestones and cherts can be definitely recognized.

Austinburg sand? (Healing Springs-Clifton Forge).—Possibly the use of the name Austinburg is unfortunate, as many geologists consider the Austinburg and Oriskany the same.

Myers[32] states that

> Oriskany sand production was found in northeastern Ohio as early as the year 1899. This producing horizon was named "Jefferson Gas Rock" and was considered at that time to be of the "lower Helderberg" age.

Several small fields were developed in this general area and from one located in Austinburg Township, Ashtabula County, the present name came into use.

Through the courtesy of Velair C. Smith, of V. C. Smith Management, a continuous set of samples from the top of the Ohio "Big lime" into the sand was made available. This well is located about 10 miles northeast of the original Austinburg pool, but the interval between the top of the limestone and the sand is essentially the same. The sediments above the Austinburg sand are composed of white to buff, fine-grained, dense, dolomitic limestone, with some brown to smoky chert in the upper part; anhydrite-dolomitic rock and brown to milky and mottled banded chert are found in the lower parts. Dolomite is found as inclusions in the chert, a condition that has been observed in the Huntersville, but not to the extent that it is developed in the Helderberg. The section for 25 feet immediately above the sand consists of dolomite-anhydrite rock with about 25 per cent white soft weathered

[31] Frank M. Swartz, "The Helderberg Group of Parts of West Virginia and Virginia," *U. S. Geol. Survey Prof. Paper 158-C* (1930).

[32] Thurman H. Myers, "Past Development and Future Possibilities of the Oriskany Sand in the Appalachian Area," *Oriskany Sand Symposium* (Appalachian Geol. Soc., 1937), pp. 21–30.

chert. A well offsetting the well examined developed oil and gas production in this zone and it may possibly represent the producing formation of these small fields. Below the weathered chert a clear to white, coarse to fine, angular to sub-round, poorly sorted sand was observed. After drilling 8 feet in the sand, water was encountered and the well was abandoned. This true silica sand may represent the water horizon found below the producing zone throughout these fields. The entire section above the sand is very suggestive of the Helderberg or upper Salina of areas at the south, and although the proof submitted is not conclusive, the writer considers this sand as a correlative of the Healing Springs, Clifton Forge sands of the West Virginia Helderberg, and possibly the equivalent of the Sylvania and the Hillsboro of Ohio.

In the foregoing area, production is controlled more by weathered chert porosity than by structure, as the fields are located in small reentrants as well as on noses.[33]

With the exception of this production in northeast Ohio, this sand is water-bearing in a greater part of Ohio and is known as the first "Big lime" water. In West Virginia only showings of sulphur gas and water have been logged at these horizons. In eastern Kentucky the upper "Corniferous" gas "pay" of Boyd, Johnson, and Morgan counties is considered as part of this series. In the latter area, production is on small structural noses and water is associated downdip with the gas.

SILURIAN SYSTEM

This system is composed of dolomite-anhydrite rocks, red, green and dark shales, limestones, and sandstones. Several unconformity zones in the Salina may be important productive zones in the basin proper, as may the Newburg (Bloomsburg) beds. In the Clinton series the Big Six (Keefer) sand is productive and the "Oölitic zones" may become important markers. The Medina series marking the base of this system has the most outstanding producing formation of the Silurian in the Clinton sand (White Medina).

SALINA SERIES

The Salina series consists mainly of dolomitic limestone that has considerable anhydrite replacement scattered through it. Probably a better term for these evaporites would be dolomite-anhydrite rock. Its upper contact with the overlying Devonian in well samples is taken at the top of the main dolomite-anhydrite rock. Several reworked water-worn fossil zones are present in this series and in West

[33] John W. Galpin, geologist, V. C. Smith Management, oral communication.

Virgina showings of oil, gas, and copious water are found associated with some of these zones. In Ohio, salt is encountered near the middle of this formation; in West Virginia most of the salt has disappeared and anhydrite and some gypsum are found. Marking the base of the Salina in West Virginia is a quartzitic sand which probably represents the Bloomsburg sand of the West Virginia outcrop section and possibly the Stadler[34] sand of the Ohio Newburg section. Below this sand Brown dolomitic shale is commonly present. Most of the variation in thickness in the "Corniferous"-Ohio "Big lime" series of rocks is found in the Salina.

Newburg (*Bloomsburg-Stadler*).—The term Newburg is very loosely applied to any production encountered in the lower part of the Ohio "Big lime"-"Corniferous" section. Production may be encountered either in crystalline sugary dolomite or in quartz sand. As the name is in such wide usage it will probably continue to be used, and where samples are not kept, cause confusion. In Ohio, south of Cleveland, this zone produces considerable gas and some oil. In this area local structure is apparently of secondary importance. In West Virginia only one well drilled through this zone has encountered production (Fig. 7, section 18). This well is located near the crest of the Warfield anticline. Gas is found in fine- to medium-grained angular to subround silica-cemented quartzitic-appearing sandstone that seems to have been re-worked in its upper limits. This sand, in a westerly direction toward the Cincinnati arch, thins and disappears and represents the "Second Big lime" water sand of Ohio and the lower "Corniferous" oil and gas sand of eastern Kentucky. McFarlan[35] considers the Irvine oil field of Estill County, Kentucky, as producing from this zone. In this latter field production is anticlinal.

NIAGARA SERIES

Directly under the Salina, shaly dolomitic limestone or pure limestone (Lockport?) is found. In West Virginia the Niagara on the outcrop is usually considered as that interval between the base of the Bloomsburg sand of the Salina and the top of the Keefer of the Clinton, although the contact actually comes above the Keefer sandstone in the Rochester shale.

CLINTON SERIES

Several important markers and sands are present in this series. In parts of Ohio, as well as in some wildcat drilling in West Virginia,

[34] W. Stout, R. E. Lamborn, D. T. Ring, J. S. Gillespie, J. R. Lockett, *op. cit.*, p. 907.

[35] Arthur C. McFarlan, *op. cit.*, pp. 1447–51.

considerable difficulty was encountered drilling this predominantly red, green, and bluish gray shale section with standard tools, due to caving. The use of heavy brines and the cement bailer has eliminated the greater part of this hazard. Correlation of the Clinton and upper Medina sands is rather confused. Two oölitic hematite zones, one or both of which have been found in all but two wells examined by the writer, should aid materially in clarifying this correlation.

Big Six sand (*Keefer*).—The "Big Six sand" was first called to the attention of the oil industry with the completion of a commercial gas well in Magoffin County, Kentucky, by the Big Six Oil Company. A few samples of true silica sand were available from these wells, but in the writer's knowledge no complete set of samples from the top of the "Corniferous" and through this sand was saved. Examination of well cuttings, from productive wells drilled to this sand in West Virginia in recent years, has shown that the "Big Six" gas "pay" is confined to sugary dolomite immediately above the contact with the sand, with probably lesser "pays" in the sand. The sand is well sorted, clear, medium- to fine-grained, angular to sub-round quartzitic sand, with calcium carbonate, dolomite, and silica cement. On the east flank of the Cincinnati arch in Kentucky, the overlying shaly dolomite or limestone is commonly absent and is replaced by dolomite-anhydrite rocks that have the appearance of being of Salina age. In these places the sand appears to be re-worked and it is highly probable that the wells in which this condition has been noted indicate that considerable erosion has taken place. Production from the "Big Six" sand is anticlinal in some of the Kentucky fields, but porosity is apparently more important than anticlinal structure. Gas from this sand is sour. The "Big Six," where present, marks the base of the drillers' "Corniferous" or Ohio "Big lime."

Ohio "Little lime" (*Dayton-Brassfield, Fossil Iron Ore zone*).—On the outcrop in southeastern Ohio, the Dayton limestone overlies the oölitic Brassfield limestone. East from the outcrop and under cover, they apparently separate in places to form two "Little limes" through eastern Ohio. Often, neither of these limes is recognized by the driller, but from sample examination, the lower can ordinarily be found. Toward the basin from the western outcrop the member changes from limestone to dolomitic limestone and in some wells is represented by dolomitic gray shaly sandstone. It is generally overlain by greenish to bluish gray shale with red shale immediately underneath. The oölites in this zone are rounded and flattened and few exceed 0.5 millimeter in diameter. In places they may extend through 15 feet of section; in other places they may be sparsely confined to less

than a 5-foot interval. Some wells in eastern Ohio have produced gas in this zone. This upper oölitic zone is apparently most persistent on the flanks of the basin, as it is absent in some wells in the basin proper. Swartz,[36] in his outcrop sections near Mount Union in central Pennsylvania, identifies a thin oölitic hematite appearing in gray limestone and green shale below the Keefer sandstone. This horizon, marking the top of the Rose Hill shale of the Clinton in the foregoing area, may be the correlative of the Brassfield-West Virginia "Fossil Iron Ore zone."

Clinton Stray (*West Virginia Iron sandstone*).—The West Virginia "Iron sandstone" on the outcrop in southeastern West Virginia is reddish brown sandstone that has many red shale partings; oölitic hematite is commonly found with this sand. Under cover, west from its outcrop, it is present as green, blue, and reddish white sandstone that may be broken into several distinct beds by intervening bluish green shale. Oölites, very similar to those found in the overlying "Little lime," are found in the bottom section of the sand. They may be scattered through a thickness of 40 feet, or may be found in only the bottom few feet. The base of the oölitic sand is separated from the underlying Clinton by 10–15 feet of bluish green to green shale. This sand is often productive in the Clinton gas area of Ohio. Here the oölites have not been found, but the sand is ordinarily hematitic. In these areas production is confined to white sand lenses associated with the red.

MEDINA SERIES

The Medina is composed of three members in West Virginia, the "White," "Red," and "Gray." The "White" Medina is the Clinton sand of the drillers; the "Red" Medina is considered as the base of the Silurian from well samples, but on the outcrop in West Virginia the underlying "Gray" is considered as the base. West from section 10 (Fig. 5), the "Gray" Medina apparently disappears as it is not identified in wells penetrating to this depth.

Clinton sand (*Whirlpool-Tuscarora*).—Considerable confusion and doubt exist about the exact correlation of the "Clinton sand" of the drillers of eastern Ohio. Possibly the tracing of the oölitic phases of the overlying Clinton to the outcrop may answer this perplexing question. The Clinton sand is extremely quartzitic in appearance. This is especially true of the upper part of the sand body. The sand is clear to bluish and greenish, angular to rounded, poorly sorted sandstone. Where productive it is lenticular, being broken with red, blue, gray,

[36] Frank M. Swartz, "Silurian Sections near Mt. Union, Pennsylvania," *Bull. Geol. Soc. America*, Vol. 45 (February 28, 1934), p. 96.

or brown shales, and has probably been re-worked. Where the sand does not exhibit this lenticular nature, no production has been encountered. In section 17 (Fig. 7), brown to white crystalline limestone, containing Brachiopoda and Bryozoa, is found interfingered with the "White" and "Red" Medina. This, no doubt, increases farther west, as the Clinton sand does not reach the outcrop in Kentucky or south-central Ohio. Below the base of the sand and separated from it by several feet of bluish gray shale, a thin sand is commonly encountered. Price considers this a transition zone on the outcrop. In this poorly sorted sand the underlying shale is found as inclusions in aggregates of sand.

"Red" Medina (Queenston-Juanita).—The "Red" Medina is red, soft or siliceous shale as shown in well records, but on the outcrop in West Virginia it contains sandstone beds in the lower part. The writer knows of no production from this formation, but where these sandstone beds are present under cover they should form a suitable reservoir.

In the central part of the basin, where the underlying "Gray" Medina has not been detected from well samples, the "Red" Medina is considered as the base of the Silurian.

ORDOVICIAN SYSTEM

The Ordovician series consists of bluish shales and thin limestones in the upper part, with carbonaceous shales and dove-colored to dark dense and crystalline limestone in the lower parts. The Sunnybrook sands of Kentucky and the Trenton of northwestern Ohio belong in this series of rocks.

Ordovician thin shales and limestones (Richmond-Maysville-Eden).—The Upper Ordovician consists of a series of thin blue shales and blue crystalline limestone. In southeastern Ohio on the outcrop, the upper part of the Richmond contains some thin purple shales that may represent a transition from Ordovician to "Red" Medina. These groups can be separated on the outcrop only by fossils, and from well samples a separation is very difficult. The upper member, or Richmond, present on the western outcrop of the basin in south-central Ohio, is not recognized as such on the outcrop in West Virginia.

In south-central Kentucky, where this series of rocks is predominantly limestone, several producing zones have been found; they are referred to as the "upper Sunnybrook sands." The oil seems to be in fracture zones although dolomitic and quartz sand lenses are known to be present in this section.

The lower part of the Eden shale is represented in northwestern

Ohio by the Utica, a brown carbonaceous shale, as characteristic a marker to the driller in these areas, as the "Brown shale" overlying the Ohio "Big lime" or "Corniferous" is to the driller in areas on the south. South and southeast of this area the Utica may interfinger with the non-bituminous shales, or it may represent what is considered by some geologists as the upper shaly part of the Trenton in the two deep wells (sections 3 and 7, Fig. 5) from which samples are available.

Trenton (*Trenton-Black River*) (*Chambersburg*) (*Cynthiana, Lexington, High Bridge*).—The "lower Sunnybrook sands" (Cynthiana-Lexington) belong in this upper part of the Trenton and probably produce from fracture zones similar to the "upper Sunnybrook."

In central and eastern Kentucky, Louise Barton Freeman[37] has experienced considerable difficulty in determining the top of the Trenton from well samples, as the entire section contains more limestone than it does in Ohio, or in the one well to reach this horizon in West Virginia. Immediately underlying the Lexington, in Kentucky, is found the Tyrone or top member of the High Bridge group. Mrs. Freeman[38] places emphasis on this contact as the Tyrone is dense, gray, dove- or cream-colored dolomitic limestone, and is in marked contrast to the overlying Lexington. The green bentonite "Pencil Cave" of the driller occurs within a few feet of this contact and aids materially in correlation. The interval between the top of the Tyrone and the St. Peter horizon in Kentucky is essentially the same as the Trenton-St. Peter interval in Ohio.

Lockett states,[39]

> Commercial production from the Trenton in northwest Ohio is confined to areas of intense stress. The pay comes in the upper few feet of the formation in open porous or cavernous dolomitic limestone. This condition is due to movement of water along fracture zones with accompanying leaching action.

Areas, with as much deformation as is found in the "Logansport sag" area of Indiana, are present in the deeper parts of the basin and should supply the same type of reservoir. A sulphurous salt water horizon is generally found with Trenton production. In Kentucky, the High Bridge series has several dolomitic and silica sand phases, that under proper conditions should provide suitable reservoirs.

As mentioned in connection with the Utica shale, the exact top of the Trenton in wells (sections 3 and 7, Fig. 5) is not located to the

[37] Letter communication through Kentucky Department of Mines to writer.

[38] Louise Barton Freeman, "Present Status of St. Peter Problem in Kentucky," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 23, No. 12 (December, 1939), p. 1839.

[39] J. R. Lockett, oral communication.

satisfaction of all. Stout[40] considers the top of the Trenton in section 3 as being at 2,100 feet with the overlying dark shaly limestone as Utica. Others, who have had access to samples from this well, consider the top at 1,930 feet and the upper part of the Trenton as shaly. In section 7 a similar condition exists. Martens[41] places the top of the Trenton at 8,865 feet; some place it at 8,780 feet; others place it below 8,900 feet.

ST. PETER HORIZON

Where the writer has observed the drillers' "Green sand" of Ohio, it consists of buff to tan, dense dolomite, mixed with soft green shale. This green shale horizon is present in all deep wells from which samples were examined in Kentucky. Mrs. Freeman considers this a bentonitic shale,[42] but Stout[43] considers it a process of weathering. This green shale horizon is found near the top of the Knox in Kentucky,[44] and Mrs. Wasson identifies what is probably the same horizon, as possibly the St. Peter horizon of western states or a sandy phase of the upper part of the lower Magnesian group.[45] In places a medium to large, rounded and frosted, clear sandstone of St. Peter type is found at this horizon. One well (section 13, Fig. 8) logged 63 feet of this sand. Whether it will extend into the basin, only drilling will show. On the outcrop in West Virginia this horizon is not recognized. At this horizon in section 3 (Fig. 5), the writer is informed typical St. Peter sand was observed. In Ohio and Kentucky showings of gas and "Blue Lick" water are ordinarily associated with this horizon, but are also found through the underlying section where penetrated.

CAMBRO-ORDOVICIAN AND OLDER

Very little is known of the formations below the St. Peter horizon from well cuttings. The Knox in Kentucky contains several sands of St. Peter type, which have had showings of gas and strong flows of "Blue Lick" water. The Vance well in Ohio (section 3, Fig. 5) encountered brines below the St. Peter, but not to the extent that they were found in the Kentucky section. Whether these horizons, if

[40] Wilber Stout and Carl A. Lamey, "Paleozoic and Pre-Cambrian Rocks of Vance Well, Delaware County, Ohio," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 24, No. 4 (April, 1940), p. 675.

[41] Rietz C. Tucker, *Deep Well Records* (West Virginia Geol. Survey, 1936), p. 431.

[42] Louise Barton Freeman, "Present Status of St. Peter Problem in Kentucky," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 23, No. 12 (December, 1939), p. 1839.

[43] Wilber Stout and Carl A. Lamey, *op. cit.*, p. 684.

[44] Louise Barton Freeman, *op. cit.*, p. 1839.

[45] Isabel B. Wasson, "Sub-Trenton Formations in Ohio," *Jour. Geol.*, Vol. 40, No. 8 (November-December, 1932), p. 679.

present lower in the basin, will continue to contain water or will contain water high on the flanks with production in the basin, like the sands of the Mississippian system, drilling only will tell. Dark shale was encountered in the Vance well in the upper part of the Cambrian, and in the Friend well[46] near Springfield, Ohio, black carbonaceous limestones of pre-Cambrian age were encountered in a section not found in wells higher on the Cincinnati arch. If these formations are proved to be at least partly bituminous and not wholly graphitic lower in the basin they can easily be important source beds.

Mrs. Wasson states[47] that the two deep wells located at Findlay, Ohio (section 2, Fig. 5) high on the Cincinnati arch, encountered 400 feet of arkosic sandstone and red shale immediately overlying red granitic gneiss. In the Vance well (section 3, Fig. 5) the writer is informed only 5 feet of red granite wash were found overlying 20 feet of arkosic sand. It is thus apparent that the crest of the arch has suffered considerable weathering and that this condition apparently decreases down the flanks. If these two cases can be taken as representative of conditions as they exist on the arch, it is very suggestive of gradual emergence with accompanying differential weathering.

As the basin area was probably subsiding during the greater part of its early development, weathering on any granite ridges will probably be found to a lesser extent.

STRUCTURAL MOVEMENTS

Information from wells drilled on the Cincinnati arch indicates that it is a buried granite ridge. Anticlines in the basin are probably much more recent although some may have had their inception as granite ridges. The northeast-southwest anticlines probably had their origin as lines of weakness in the "Basin complex," but the north-south anticlines are probably of much later origin. As a whole they constitute a relatively negative element as compared with the Cincinnati arch.

Evidence of submergence of the basin in relationship to the arch, is present from well-log data as early as the pre-Cambrian. Dark limestones and shales are present in wells at Springfield and Columbus, Ohio, which are not present in wells near the crest of the arch and definitely suggest subsidence. Following this early movement, the arch in Kentucky, as well as Ohio, was apparently static until late Ordovician when movement again is indicated in the thinning of these shales over the arch in both Kentucky and Ohio, as well as limestone beds interfingering into the overlying Medina, as the arch is ap-

[46] *Ibid.*, p. 682.

[47] *Ibid.*, p. 675.

proached from the basin. This movement continues through Medina time as the Clinton ("White" Medina) does not reach the outcrop on the arch. From well records, the first suggestion of movements on anticlines in the basin began at this time. Likewise the lower Clinton (West Virginia Iron sandstone) does not crop out on the western side of the basin. During middle Clinton a more or less static condition must have prevailed, as the Brassfield-Fossil Iron Ore zone, exposed on the outcrop, is found well down on the flanks of the basin and near the crests of some of the northeast-southwest anticlines. Possibly in late Clinton or early Niagara time this static condition was disturbed, as the Keefer (Clinton) sandstone approaching the arch from the basin appears re-worked in much of its upper part. This sand disappears before reaching the outcrop and the limestone or shaly dolomitic limestone overlying it is replaced by dolomitic-anhydrite rocks (Salina). The limestone or shaly dolomitic limestone is probably of Niagara age. It, like the underlying "Big Six," disappears before reaching the outcrop near Irvine, Kentucky, but is represented on the outcrop in south-central Ohio by a section only slightly thinner than it is under cover, well down on the flanks of the arch in eastern Ohio.

The Salina is the thickest member of the "Corniferous"-Ohio "Big lime" rocks and most of the variations in thickness in the basin occur in this series. Whether this is due to the nature of the source sea or whether it is due to crustal movement, it is difficult to say, as this thick series examined under a binocular microscope looks essentially the same; however, the re-worked appearance of the Bloomsburg sand from some wells, and the water-worn fossil zones are very suggestive of movement, and as the Salina does not reach the outcrop in Kentucky, but may be represented in the Ohio outcrop by only a thin section, crustal movement must have occurred. During early Devonian time the arch was apparently very active. This is evidenced by the absence of the basal part of the Devonian near Irvine, Kentucky, and Columbus, Ohio, as well as the patchy remnants of the Boyles (Onondaga-Hamilton) limestone near Irvine, Kentucky. During Middle Devonian shale deposition, the shales thin toward the arch and on the western outcrop interfinger, or are replaced by limestone. This movement was slightly retarded during early Upper Devonian when the Olentangy shale was deposited. This shale, although thin on its western outcrop, is apparently present throughout the basin and may reach the western outcrop. During the remainder of Devonian time, movement must have continued as is evidenced by the interfingering "Brown shales." The development of independent Mississippian, Pennsylvanian, and Permian basins indicates that this condition must have

continued through these times, and if slight earth adjustments are considered, is still in process.

Two general trends of weakness are in evidence in this basin: northeast-southwest and north-south.

NORTHEAST-SOUTHWEST ANTICLINES

The northeast-southwest movement is best expressed by northeast-southwest anticlines, for example, the Irvine Paint Creek uplift in Kentucky, and the Warfield-Chestnut Ridge anticline in West Virginia and Pennsylvania. This folding probably has its origin in part as an old granite ridge, or as a line of weakness in the basement complex. It is expressed in a series of *en échelon* folds with the steeper flanks on the southeast. Near the Appalachian structural front this condition is reversed.

Information on the older sediments from well data is very meager through the entire basin. It appears as if the Warfield anticline was a relatively positive element as early as Lower Silurian time, and probably earlier. The Bull Creek Coal Land Company well No. 13, of the Owens, Libbey-Owens Gas Department (section 18, Fig. 7) near the crest of the Warfield anticline, discovered gas in the White Medina sandstone. The Joe Hill No. 1, drilled by Benedum-Trees Oil Company 9 miles northwest of this well and far down on the north flank of the Warfield, was dry. From sample examination of the Medina sand from these two wells, the sand in the Bull Creek No. 13 well appeared to be re-worked, but the sand in the Hill well was not. In Ohio east of the Medina production, the sand is present in a solid unbroken section. The productive area is confined to the shore line of the old Medina sea where the sand has been re-worked and re-deposited as a series of lenses. Apparently the Warfield anticline was an island or positive element during Medina time, and the re-working conditions on this anticline were similar to those along the Medina shore line on the east flank of the Cincinnati arch in Ohio.

Following the possible movement during Medina time, the Warfield was apparently relatively quiet, as the section from the Clinton sand to the Big Six (Keefer) in wells exhibits essentially the same interval. This appears to have continued through Niagara and possibly Salina time.

During early Devonian time there is some evidence of the Warfield and other anticlines with northeast-southwest trends being relatively positive elements. In Figure 3, the thickness of the Oriskany sand as logged in wells is shown. The Oriskany water table that narrows perceptibly over the Warfield-Chestnut Ridge is also indicated.

The thinning of the sand from the Elk-Poca field, where an average thickness of 60–70 feet of sand is found, to the Campbell-Davis Creek field where the sand has thinned to 17 feet, is very suggestive of movement. Immediately south of this area near the crest of the Warfield anticline only 11–14 feet of sand are found. In the Bull Creek Coal Land Company well No. 12, of the Owens, Libbey-Owens Gas Department, a total thickness of 11 feet of Oriskany sand was drilled, and commercial gas was developed. Bull Creek Coal Land Company No. 13 was drilled 2,500 feet southeast of this well near the crest of the Warfield, as expressed on the "Corniferous" (Middle Devonian), and was less than 20 feet structurally higher, yet encountered 36 feet of Oriskany sand broken with chert and limestone, as well as having an exceedingly high content of glauconite. This is very suggestive of a shore-line condition. A. C. McFarlan[48] and Charles W. Wilson, Jr.[49] postulate a distinct resurgence of the Cincinnati arch during mid-Devonian time, as expressed by the overlap toward the axis of the arch during this period. The absence of the Detroit River series on the outcrop at Columbus points to the same conclusion. This movement must have continued through Devonian time as a Berea (basal Mississippian)-"Corniferous" (Middle Devonian) convergence map shows a distinct thinning over the Warfield anticline. The Berea sandstone thins and practically disappears near the crest of the Warfield, but is present in normal thickness on both sides. Following Berea time there is no evidence of movement that can be positively detected from detailed well records, but it must have continued through the Appalachian revolution as evidenced by Pennsylvanian and Permian basins and surface indications of faulting.

FAULTING

From the southwest rim of the basin, where the Cincinnati arch is intersected, surface mapping reveals a well developed fault pattern that can be traced into West Virginia, where surface indications are difficult or impossible to find. Near the West Virginia-Pennsylvanian State line, where the Chestnut Ridge anticline is emerging from the deepest part of the basin, subsurface faulting is indicated, but is reflected as only steep dips on the surface. Surface indications of faulting are found on the south side of the Warfield anticline in its western development, but northeast of Logan, West Virginia, few, if any, surface

[48] Arthur C. McFarlan, "Cincinnati Arch and Features of Its Development," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 23, No. 12 (December, 1939), p. 1848.

[49] Charles W. Wilson, "The Pre-Chattanooga Development of the Nashville Dome," *Jour. Geol.*, Vol. 43, No. 5 (July–August, 1935), p. 479.

indications can be found. However, definite indications are present in shallow subsurface mapping, and these are more pronounced with depth. Not enough information is available to determine the nature of the faulting, but it is apparently of the thrust type and is possibly underthrust. The crest of the Warfield, from subsurface data, may be faulted in a similar manner, as is found from subsurface mapping of structures in northeastern Pennsylvania. Very little deep prospecting has been done along the Chestnut Ridge anticline in West Virginia, but it is believed more intense faulting than indicated on the Warfield will be found.

NORTH-SOUTH ANTICLINES

The age of anticlines with a north-south trend, for example, Man Mountain and Burning Springs, are much more difficult to postulate than is the age of the northeast-southwest anticlines.

The writer has previously considered their age similar to or greater than the age of the northeast-southwest trends. He now believes that these structural movements are much younger than the northeast-southwest trends. Only one well (section 6, Fig. 5) has been drilled as deep as the Clinton ("White" Medina) near the axis of the Burning Springs anticline, and this Lower Silurian section exhibits no changes in interval other than normal thinning in the direction of the Cincinnati arch. The Silurian and Lower Devonian both appear to be normal with a thick section of Oriskany sand on the crest of the structure. A Berea-"Corniferous" convergence map shows evidence of thinning over this anticline and suggests that during Middle or Upper Devonian time this structure was a positive element. During Mississippian time the structure was definitely positive as exhibited by the sporadic Berea (basal Mississippian) and possibly Greenbrier depositions. Less prominently developed structural trends, roughly paralleling this movement, are found both on the east and west.

FAULTING

There are indications of faulting of considerable magnitude on the eastern sides of these structures. It is thought that some of the early deep wells drilled on the Burning Springs anticline were drilled in such a zone, which is indicated on the surface by exceedingly steep dips, but is probably a thrust fault in the older formations.

SUMMARY

Considerable confusion has prevailed in the literature due to the nomenclature used in referring to the Appalachian geosyncline. The name Pittsburgh-Huntington is suggested for that northeast-south-

west synclinal area cutting the basin in which are found the youngest consolidated sediments (Permian) thus far found in the Central basin. It is suggested that the name Parkersburg-Lorain be applied only to that north-south synclinal area extending from Lorain, Ohio, and continuing south to a point near Parkersburg, West Virginia.

Accumulation of oil and gas in most of the silica sands in the Central basin is primarily a matter of proper sand conditions, with anticlinal structure of secondary importance. Devonian shale gas production is apparently related to the lower margin of an epi-continental shelf that helped create a fracture-type reservoir.

The thick "Corniferous" and Ohio "Big lime" have been examined microscopically and various sands tentatively correlated. In the Clinton series the recognition of two hematitic oölite horizons may be important in the proper placement of the "Clinton" sand.

Structural movements beginning as early as pre-Cambrian and continuing with interruptions through the Permian are discussed on the basis of well-log data. The development of independent Permian, Pennsylvanian, and Mississippian basins suggests that lateral and rotational forces were at work during these periods which were not active during the development of the major Central basin. Two directions of folding, northeast-southwest, and north-south, are recognized. Based on well records, the earliest indications of movement on the northeast-southwest anticlinal trends occurred during Medina time and on the north-south trends movement apparently began in late Devonian.

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SEDIMENTS OF FRESH-WATER LAKES[1]

W. H. TWENHOFEL[2] AND V. E. McKELVEY[2]
Madison, Wisconsin

ABSTRACT

The sediments of fresh-water lakes are deposited in response to the various environmental factors present in lakes that have sedimentary control. Among these are the origins of the lake basins, size and depth of basins, relief of drainage areas, extents of shallow water adjacent to shores, degree of vegetable protection over drainage areas, characters of surrounding rock and soil terranes, climatic conditions, and organisms dwelling in lakes. The plan of lake deposits is considered and the characters of the sediments deposited in lakes are described in detail. Deposits of different lakes have individual characteristics and this is the case even in lakes which are close together. Rates of deposition vary with lakes. Deposits over the deep parts of almost every lake contain a high content of matter of organic origin. Profound changes take place in lake sediments after their deposition. Organic matter is eliminated, the content of carbonates may increase or decrease, and there are other important changes. There is much formation of combustible gas, thought to be methane, and a paraffine wax has been extracted. Bacteria and other micro-organisms are responsible for these changes.

INTRODUCTION

Erosion and deposition by glaciers are responsible for more lake basins than the aggregate of all other causes and, due to the recentness of the last Ice Age, lakes and their deposits are numerous over the glaciated areas. Lakes are generally absent over unglaciated upland areas, but they are not uncommon along sea shores, in river valleys, and in regions that have experienced considerable recent faulting as in the Basin-and-Range province of the United States and the Rift Valley region of Africa.

Lake basins may be expected ultimately to disappear, either because of filling or of lowering of outlets, and, either during disappearance or subsequently, the sediments deposited in lakes may be expected to be extensively, and perhaps completely, removed. Lake sediments may, thus, be expected to have a more or less ephemeral existence, this being particularly true for the sediments of upland lakes such as are so many of those over the glaciated areas of the last Ice Age. The sediments of lakes of lowland areas have greater possibilities of preservation.

Studies of lake sediments have been largely confined to those of existing and recently extinct lakes (11).[3] The Green River shales of an ancient Tertiary lake have been studied by Bradley and others and some attention has been given to some varved shales considered to have been deposited in ancient glacial lakes. Approach to this branch

[1] Manuscript received, October 5, 1940.

[2] Department of geology, University of Wisconsin.

[3] Numbers in parentheses indicate references at end of article.

of sedimentary geology is thought to be best made through studies of modern lake sediments. After the characters of modern lake sediments have been learned, the knowledge acquired may be used to identify sediments of lacustrine origin in the geologic sequence.

Sediments are products of inheritance and environment. This is as true of the sediments of lakes as of those of other realms of sedimentation. The sediments deposited in lakes depend on many environmental factors. Combinations of these factors are almost infinite, are probably different for each lake, and also different in each lake from time to time. The characters of the sediments should reflect the combinations. Important factors of sedimentary control are the origins of the lake basins, size and depth of basins, relief of drainage areas, extents of shallow waters adjacent to shores, degree of vegetable protection over drainage areas, characters of surrounding rock and soil terranes, topography of bottoms of basins, circulation of lake waters, climatic conditions, character of lake water, organisms in lakes, thermal stratification of lake water, and sources of lake sediments. These various factors are considered in as much detail as seems necessary.

The writers' studies of lake sediments have been largely limited to fresh-water lakes of the upper Mississippi Valley and the considerations presented on the following pages may thus be thought to reflect a somewhat provincial attitude. The literature relating to lake sediments, however, has been studied and it is believed that most of the generalizations suggested have somewhat general application. Results so far obtained indicate that the sediments of each lake are to some degree of individual character.

FACTORS OF SEDIMENTARY CONTROL

ORIGINS OF LAKE BASINS

Lake basins result from damming, excavation, and crustal movement. Damming is probably responsible for most basins, crustal movement for fewest. Dams may be built in standing waters by construction of bars across bays, building of spits which ultimately connect with shores, building of two bars to connect an island with the shore, building of bars which connect with the shores at both ends, or as river deposits on deltas to enclose some parts of the standing water. A dam may also be made by a tributary across the stream into which it flows, as Lake Pepin between Wisconsin and Minnesota, across the ends of a former channel of streams as the oxbow lakes of floodplains, by a glacier depositing a moraine across a valley or by successive morainic deposits to enclose basins, by sand dunes, by mud flows or

land slides filling places in valleys, by lava flows passing down a valley and damming all tributary valleys, or by falls of volcanic ash to enclose basins. Dams are also made by beavers and man. Outlets of basins may become clogged with vegetation and thus make basins deeper and of greater extent.

Basins due to excavation are produced by glaciers, streams, volcanic explosions, solution, and man.

Basins of structural origin result from downwarping or upwarping of a part of the earth's crust, or by adjustment—faulting—of crust blocks. These are among the largest and deepest lakes.

Basins may be due to combinations of causes, as those produced by relative fall of sea-level to change a sea bottom to land areas. The sea bottom may have been made by differential deposition of various kinds of sediments, thus forming basins, and the change in sea-level may have been accompanied by some warping or faulting.

The origins of lake basins may have little influence on the sediments deposited in them. Thus lakes of upland areas, whether due to damming, excavation, or structural factors, may have few or no sediments which are related to the methods of origin of the basins after the causes of origin have ceased to have direct effect. On the other hand, lake basins produced by stream processes, as the damming of tributaries, or damming both ends of deserted channels, are in position to be affected repeatedly by the processes that created the basins, and sediments may be deposited in them from time to time by the streams to which the lakes owe origin. The same is true for lake basins formed along sea shores. The lakes in these basins from time to time may receive sediments from the sea and these sediments show relations to the parent body.

SIZE AND DEPTH OF BASINS

The size and depth of a basin may be related to origin. Some of the largest and deepest of lakes are of structural origin. Lakes of glacial origin are of all sizes and depths. The largest and deepest of the glacial lakes are due to over-deepening and damming of pre-glacial valleys. Other glacial lakes, although they may be large, are mostly less than 100 feet in depth. River lakes may attain great size, particularly in length, but most of them are shallow. Basins due to volcanic explosions may be of large size and great depth.

Under humid conditions the size and depth of a basin determine the size and depth of the lake therein. The size and depth of a lake determines the strength of waves, and thus their attack on the shores and bottom, and the character of the shore and bottom deposits. If the

lake is large, wave action may be severe and attack on the shores may be vigorous and erosion of the shores correspondingly great. The waters of shores subject to vigorous wave erosion have much turbulence and this may result in high turbidity. The turbidity develops a density or turbidity gradient from the shores outward to deeper waters. If the lake bottom is not below wave base continual reworking of the bottom deposits will occur where they are permitted to accumulate at all.

If lakes are small, waves are weak, wave attack on shores small, and plants accordingly colonize shallow bottoms and shores. Inorganic sediments derived from shores are limited, and organic sediments brought to, or deposited outward from the shores, are correspondingly larger.

Deposition may proceed more slowly on large and deep lakes than on small shallow lakes, due to the greater distances of much of the bottom from shores and source materials and due also to the more profuse growth of plants on and over shallow bottoms.

The size and depth of lakes have a direct bearing on the extent of currents present and are limiting factors where circulation is concerned. Processes of chemical deposition and diagenesis may be directly related to the size and depth of lakes as these factors affect conditions of oxidation, reduction, temperature, and agitation of the water.

RELIEF OF DRAINAGE AREAS

The relief of surrounding drainage areas may range from little to very great. Under conditions of low relief the surface waters resulting from rain or melting snow travel slowly from places of falling or melting to the lakes to which they may bring little in suspension, but perhaps much in solution. If relief is great, surface waters move rapidly, have great competency and capacity, and are likely to carry much material in suspension. Under conditions of little relief, attack on shores by erosive agents yields the eroded products only as a consequence of direct attack, whereas under conditions of relief permitting formation of cliffs as a consequence of wave attack, much more or less broken rock is thrown on shores through undermining, an indirect result of wave attack.

EXTENT OF SHALLOW WATER ADJACENT TO SHORES

Wide, shallow bottoms adjacent to shores serve as protection of shores against wave attack. Such bottoms tend to become covered with vegetation and thus energies of waves are dissipated by the shallow bottoms and vegetation before shores are reached. There is

thus limited acquirement of inorganic sediments from shores and considerable acquirement of organic sediment from the vegetation over the shallow bottoms.

DEGREE OF VEGETABLE PROTECTION OVER DRAINAGE AREAS

Drainage areas covered with lush growth of vegetation permit little water under ordinary conditions to leave by direct run-off. The water is absorbed by the sponge of living and dead vegetable matter, sinks into the substratum, and then pursues devious paths to lower levels. On the other hand, absence of vegetable protection permits most water to flow away easily. The blows of the falling waters are not broken by vegetation, the waters are muddy immediately after falling, the surface of a soil containing clay particles becomes wet, pores in the soil are quickly closed by mud in the waters, and thus runoff is compelled. Movement tends to be rapid, turbulence to be great, and large loads of suspended matter may be brought to lakes by numerous streams ranging from small to large. Waters at stream mouths become highly turbid, turbidity gradients are established, and density currents move to deeper waters. The drainage area of every lake holds some position in the range from little to excellent vegetable protection and sediments brought to any lake by surface flow from drainage areas are in some degree of qualitative and quantitative adjustment to the vegetable protection over drainage areas.

Since the advent of extensive clean-tillage agriculture the absence of vegetable protection has produced intensified results. Clean tillage has systematically destroyed protection and, in addition, has pulverized the soil so as to make it easy to be carried away. The effects of human occupation of a region should be reflected in sediments deposited after occupation even if one disregards the very obvious articles of human culture such as bottles, pieces of coal, *et cetera*.

Crystal Lake and Little Long Lake in northern Wisconsin are in basins due to glacial or fluvio-glacial deposition. These lakes until recently were surrounded by a dense growth of coniferous and other vegetation. Inflow into each lake is over plant-covered slopes and through swamps. There is little possibility of acquiring inorganic materials from the surface. The evidence seems to indicate that sediment accumulation in the deep parts of each of these lakes in the time since the departure of ice sheets—estimated at about 25,000 years—has been about 2–5 meters. More than half of the thickness is represented by water. The sediments are very high in organic matter and tests of diatoms. Strictly inorganic matter has secondary importance. These relations are due to vegetable protection and also to the fact

that the surrounding terranes do not yield calcareous matter to solution (14).

An excellent cover of vegetation compels much water to soak into the ground and thus slowly to pursue its way to lower levels. It may find egress through the bottom of a lake, or if the bottom is sealed by sediments, at the upper level of the water in the lake. The waters may be high in dissolved substances.

CHARACTER OF SURROUNDING ROCK AND SOIL TERRANES

Lake basins must be margined by some kind or kinds of rocks. These may be sedimentary or igneous. If sedimentary, they may be calcareous, ferruginous, argillaceous, carbonaceous, or siliceous, and, if igneous, acid, intermediate, or basic. The dissolved and suspended sediments derived from the various rock terranes are related to their sources and the waters entering lakes after flowing over and through the materials of the terranes express something of their chemical characters. Thus, waters flowing through, or over, calcareous terranes contain calcium carbonate if the rocks are calcitic limestones, and calcium and magnesium carbonates, if the rocks are dolomitic limestones. The lakes are then hard-water lakes. If the terranes contain calcium sulphate or sodium chloride, the lake waters carry these salts in solution to a greater or less extent. If the terranes contain little or no calcareous or other readily soluble materials, the waters are soft. There are all gradations between the extremes. Devils Lake in the Baraboo region of Wisconsin (15) is surrounded by pre-Cambrian quartzites and receives inflow very largely from these terranes. The waters carry very little calcareous matter in solution and the sediments deposited in this lake are almost wholly non-calcareous. Lakes Mendota and Monona in the vicinity of Madison, Wisconsin, about 35 miles south, are surrounded by dolomitic limestone terranes and the water of each lake is hard and the deposits are largely calcium carbonate (13).

Some soils erode easily, others with great difficulty. This should be qualitatively and quantitatively expressed in the sediments carried from the different soil types into adjacent lakes.

TOPOGRAPHY OF BOTTOM OF A LAKE BASIN

The topography of the original bottom of a lake basin may reflect the origin of the basin. Lakes formed by damming of over-deepened pre-glacial valleys are steep-sided, with the bottom more uniform in character. Lakes of kettle origin may be steep-sided but tend to have irregular bottoms, particularly if they are large, or represent basins

formed by more than one ice block. The original bottoms of river lakes may be regular or irregular and reflect such features as channels, bars, and flood plain.

Erosion of areas above wave base, whether adjacent to shore or not, and deposition on those areas below wave base tend to smooth out irregularities of the original bottom.

Wide, shallow bottoms adjacent to shores serve as protection of shores against wave attack. Such bottoms tend to become covered with vegetation and thus energies of waves are dissipated by the shallow bottoms and vegetation before shores are reached. There is thus limited acquirement of inorganic sediments from shores and considerable acquirement of organic sediment from the vegetation over the shallow bottoms.

Lake basins may have regular or irregular bottoms. If the bottoms have topographies that favor limited circulation in some places, the waters in these places become essentially stagnant and low in oxygen, organic matter does not decay, and the sediments are likely to be organic rich muds. If lakes are very deep and are fed by shallow and small inlets and drained by shallow outlets, circulation over bottoms is likely to be poor. Of this character are marine indentations like the fiords of Newfoundland and Norway which are deep inland and have shallow thresholds at connection with the sea.

CIRCULATION OF LAKE WATERS

Some circulation of lake waters is due to density currents determined by temperature or material in suspension or solution, some to currents connected with waves, and some to the quantity of water flowing through lakes from inlets to outlets. If inlets are small and few and outlets are shallow, circulation due to flow of water through a lake is likely to be confined largely to the surface. This may also be the case if the inlets are large and topography of the bottom of the basin is such as to prevent deep circulation. If the currents produced by streams flowing into lakes travel deep from any cause, there is likely to be excellent circulation, bottom waters are provided with oxygen, and organic matter is destroyed. Poor circulation permits organic matter to accumulate.

CLIMATIC CONDITIONS

Climate has direct influence on the nature and extent of rock decay about drainage basins, extent of vegetable protection, quantity of rain or snowfall, extent of evaporation, presence or absence of lake outlets, annual occurrence or total absence of an ice cover, and other con-

sequences. All of these factors affect the quantity and quality of sediments that enter and are deposited in lakes. If a lake has an ice cover during winters, sands and pebbles are readily blown from shores to places on the ice. Melting of the ice permits these to drop to the bottom. Under certain climatic conditions lakes undergo semi-annual overturns. These take place under those climatic conditions which have ranges of temperature that extend across the condition of greatest density (4°C. for distilled water). This leads in autumn and spring to surface waters becoming more dense than waters on the bottom, causing surface waters to sink and bottom waters to rise. Overturn is particularly characteristic of lakes that freeze during winter. The overturns take place just before freezing and just after melting, but freezing is not essential for overturn to take place. Each overturn brings oxygen-laden waters to the bottom and drives waters filled with carbon dioxide to the top. Overturn permits bottom waters and deep bottom sediments to be inhabited for some considerable time each year by aerobic organisms with attendant destruction of organic matter. At other times, oxygen becomes exhausted, carbon dioxide accumulates, waters become poisonous, and aerobic organisms are killed or expelled. Anaerobic organisms continue destruction of organic matter, but probably at a much reduced rate.

If climatic conditions are such that surface waters remain lighter than bottom waters, overturn does not take place and bottom waters, unless stirred by waves and currents, are permanently without oxygen, or low in oxygen, and inhabited by anaerobic organisms. The condition of no overturn is characteristic of fresh-water lakes of tropical and subtropical regions in which surface waters are permanently warmer, and hence permanently lighter than bottom waters. It is also characteristic of lakes of very cold regions in which the bottom waters tend to be maintained at the condition of greatest density (4°C.).

ORGANISMS IN LAKES

Lakes are inhabited by fish, frogs and tadpoles, gastropods, pelecypods, crustaceans, sponges, annelids, larvae of several kinds of insects, bacteria, diatoms, algae, and representatives of a few other groups of organisms of which none has particular importance. Fish naturally dwell wherever there are oxygen and food as do also the other nektonic forms and also the plankton. Lakes with semi-annual overturn permit these organisms, other conditions being favorable, to go to the bottom waters above the sludge. Large benthonic organisms with few exceptions dwell on bottoms shallower than about 6–10 meters, depending on the size of the lake. The limiting lower depth

may be much less than 6 meters in small lakes. Most large benthonic organisms avoid bottoms composed of sludge and few or no kinds of benthonic organisms live on or in this sediment. The writers have seen few sedentary benthos dwelling on sludge. Samples of sludge have been found to contain very slender worm-like animals with length of 2.5–3 centimeters. Shells naturally dwell with difficulty on bottoms underlain by material of the consistency of sludge as they would sink into it and be smothered. There is thus only a narrow belt along shores that is adapted to support benthonic organisms and ordinarily they do not dwell there in large numbers. This is the case even on lakes as large as Lake Ontario which Kindle (7, 1925) reports supports "the great bulk of the species" on bottoms of depths which rarely exceed 8 meters and beyond this depth the bottom consists of black muds—sludge—inhabited only by a few worms. In sludge taken from Lake Mendota and placed in a 5-gallon glass bottle it was found that small worm-like animals repeatedly traveled up and down through the sludge.

Studies made of the sludge of Lake Mendota and Trout Lake of Wisconsin have shown that the upper part of this sediment to the depth of about a foot contains a population of macro-organisms beneath each square meter that ranges from 577 to 4,006 in Trout Lake and from 800 to 33,800 in Lake Mendota. Many are larvae of insects. As a consequence, variations of the population are seasonal (6a). These organisms more or less thoroughly knead the sediments.

In no one of the lakes so far studied has shell matter been found to be very important. A few shells of pelecypods, shells of a few species of gastropods and a few fish bones represent all that has been seen. Some older marls in former lakes have been found filled with gastropod shells which are mostly those of *Physa* and *Planorbis*.

Bacteria inhabit the sludge in large numbers and great variety. The firm muds beneath the sludge also contain many bacteria, particularly the top several inches. There is a decline in numbers with increase in depth. Bacteria seem to be more numerous in sludge from eutrophic lakes than in sludge from oligotrophic lakes. No studies of dystrophic lakes have been completed. Crystal Lake, a very clear soft-water lake of northern Wisconsin with oligotrophic bottom waters, has limited numbers of bacteria in its sludge. Plants are abundant in some lake waters. Important forms are arrow leaf, pickerel weed, pond lilies, various grasses and reeds, various mosses, and fungi. Some live on the bottom, others float, and the grasses and reeds colonize the shores and very shallow parts of the bottoms. Their dead remains make additions to the sediments. Plants dwelling on the shores add leaves, stems, pollen, *et cetera*.

THERMAL STRATIFICATION OF LAKE WATER

The waters of lakes are stratified on the basis of temperature into the epilimnion, or upper waters that have temperatures varying with that of the region but with somewhat less range; hypolimnion, or bottom waters with relatively constant temperatures throughout the year; and thermocline, a middle zone arbitrarily defined as that zone of water in which the fall of temperature exceeds 1°C. per meter increase in depth. The conditions in the three zones are different and these conditions have impact to some degree on the life and ultimately on the sediments of the three zones (7, 1927).

CHARACTER OF LAKE WATER

The chemical character of lake waters depends on the quantity and kinds of materials in solution. Some materials in solution are dependent, as already noted, upon the waters that enter lakes either through surface or subsurface drainage. The geographical and physical nature of the surrounding terrane usually determines the characters of the surface drainage, but the subsurface drainage may or may not be able to enter below lake level. The quantities of oxygen and carbon dioxide entering lake waters are largely dependent on circulation. Oxidation of organic matter also makes additions of carbon dioxide and some oxygen is released by the activities of plants. Biological conditions in lake waters are responsible for other substances in solution. On the basis of oxygen and nutrient materials in bottom waters of lakes they may be classified as eutrophic with little oxygen and much nutrient matter, oligotrophic with much oxygen and little nutrient matter, and dystrophic with little oxygen and little nutrient matter (1). Naturally, there are all gradations. Life is greatly influenced by these conditions.

SOURCES OF LAKE SEDIMENTS

The inorganic sediments deposited in lakes have various sources, the three most obvious being underground waters, streams, and shores. Streams derive sediments from the regions drained and those brought to lakes are like those transported by streams everywhere, that is, tractional matter rolled on the bottom, visible suspended matter, matter of colloidal dimensions, and substances in solution. The tractional loads and the suspended loads that are not colloidal tend to be dropped adjacent to places of entrance, but some silts and clays may be carried to deep bottoms if the waters of entering streams are colder than those of the lake entered, or if the waters are sufficiently turbid to produce fairly large turbidity gradients under which conditions density currents due to load may carry sediments to deep

bottoms. The colloidal materials contributed by streams may be expected to continue movement through lakes to outlets unless they sink into currentless waters or become flocculated after which they sink slowly and may attain deposition. The dissolved materials may be expected to undergo some loss by organic extraction and in the case of carbonates there may be some precipitation and deposition because of escape of carbon dioxide. Most dissolved materials contributed by streams may be expected to leave lakes by outlets.

Sediments derived from shores undergo more or less the same history as those derived from streams. They may differ from the fluvial sediments in not being so far advanced in decomposition and they probably also have a more local origin. The sediments of shore derivation are transported outward in solution, in suspension, and by traction. The stirring-up of the sediments in the shallow water by wave action creates a turbidity gradient which produces density currents that move from the shallow to deeper waters carrying with them the sediments that cause turbidity. It is known that considerable sand is floated from shores on the surface of water and some of this is of granule or even larger dimension.

Some sediments are derived from springs and from seepage. It is probable that most of these are colloidal and water soluble. Their histories are like those of similar materials whatever the source.

All lakes receive sediments from the atmosphere. Most of this is of small dimensions and may be far traveled. Since the development of extensive clean-tillage agriculture the atmosphere has carried much material of local origin into lakes of cultivated regions. Some is probably dissolved shortly after settling on water. Not all is deposited as currents carry some to outlets. Lakes that are coated with ice during winter may have much sand and pebbles blown upon the ice from the shores. These sediments settle to the bottom on melting of the ice and introduce components into fine-grained sediments that may seem unnatural.

Organisms are important sources of lake sediments. Lakes are inhabited by planktonic, nektonic, and benthonic animals. Some construct shells and exoskeletons, others bones or some form of internal skeleton as the spicules of sponges. All contribute organic matter in the form of excrement and dead bodies. Shells and exoskeletons are mostly composed of calcium carbonate and chitin. There is probably some phosphate, and sponges contribute silica. Plants belong to the benthos and plankton and consist of algae, higher plants, diatoms, bacteria, and a few fungi. The fungi may be disregarded as relatively unimportant sources of sediments although they may play an important part in the decomposition of organic matter. The algae and

aquatic higher plants contain chlorophyll and these precipitate carbonates of which that of calcium is the most important. Diatoms make tests of silica and under favorable conditions they may be responsible for most of the sediments on some lake bottoms. All plants and animals contribute organic matter composed of proteins, cellulose, lignin, fats, waxes, gums and resins. In addition to plant matter produced in lakes, large contributions are brought by streams and the atmosphere. There is little doubt that organic contributions to the sediments of lakes are large and in many lakes their importance transcends that of inorganic sediments. Preservation is another matter.

PLAN OF LAKE DEPOSITS

The plan of many lake deposits reflects the mode of origin of the basin. Glacial lakes of excavation are commonly elongate and follow a regional pattern. Lakes formed by the damming of valleys are also commonly elongate and may follow the regional drainage pattern. Many river lakes are elongate and may be of crescent shape, following meanders and oxbows. Lakes of crustal or structural origin may have various shapes depending on the movement or structure involved. Lakes of solution, eruption, and kettle origin are commonly circular to elliptical in plan.

The sediments of the original bottom, if below wave base, may remain unmodified throughout the history of the lake, and reflect directly the processes responsible for the origin of the basin. If these sediments are above wave base they may be modified by wave action so as to have little relation to origin. Thus, depending on the origin of the basin, the materials of the original bottom may be coarse or fine, homogeneous or heterogeneous in distribution, and lithified or unlithified.

The first or basal deposits of the lake may bear some relation to the origin of the basin, particularly if deposition in the deeper areas does not proceed rapidly enough to prohibit reworking of the deposits of the original bottom. Again, they may be coarse or fine depending on the factors involved in deposition and source of the sediments.

Under some conditions waters more or less gradually fill a basin, so that theoretically every part of a basin at one time was a shore. If filling of a basin is rapid, the shore deposits at each step in the filling with water are of little import and may be nonexistent. If filling with water proceeds in leisurely fashion so that each shore is washed for a long time, there may be shore deposits of some degree of coarseness at the base of every section, and if they are coarse, they form a marginal or basal conglomerate.

The coarsest sediments should be on the margins but it does not

follow that the marginal sediments are coarse. Coarser sediments may also be found near islands, or other parts of the original bottom which were at some time above wave base. Sediments of sand dimensions in most lakes may hardly be expected to extend more than a few hundred yards from shore.

The summit deposits of a filled lake basin may be fine or coarse. The latter is likely to be the case in some of the deposits found in ice-dammed lakes formed about the fronts of the Pleistocene glaciers. In these, lake levels fell as the ice dams melted away and a shore deposit was left as the waters fell. If, however, filling occurs while the lake level is stabilized, the shore advances over the filling, waters adjacent to the retreating shores are likely to become shallow and the summit deposits, instead of being coarse, are likely to be organic-rich muds. This is not in accord with the view once expressed by another investigator that the deposits of a lake should be coarse at the base and also on the summit (8).

SEDIMENTS OF LAKES

Inorganic sediments of lakes range from boulders to sands in the larger dimensions and from silt to clay in the smaller. The coarse sediments, if present, have more or less limited distribution over all bottoms where currents are not so strong as to make it impossible for them to stay. Sediments of organic origin are marls, diatomite, iron hydroxide, manganese oxide, and various kinds of strictly organic sediments (tissues, woody matter, *et cetera*), all in various stages of decomposition. The sediments of organic origin tend to be distributed over bottoms beginning short distances from shores and in shallow depths, but in small lakes and some bays of large lakes they may extend to shores. The marls and diatomites are mingled in all proportions with the strictly organic and inorganic sediments. The strictly organic sediments are in various stages of decomposition from the original composition of proteins, cellulose, lignin, fats, waxes, gums, and resins. Due to environmental differences the organic sediments may be expected to vary more or less with each lake and because of selective decomposition the organic sediments buried in one lake may have quite different composition from those buried in another lake and they also may vary from time to time in the same lake. The organic materials consist of recognizable stems and leaves, macerated plant fibers, pollen grains and exines, spores and spore cases, and minutely divided plant and probably also animal matter from fine to colloidal dimensions.

The organic sediments of lakes seem to be largely of plant origin.

They have been termed sapropel. This term has been used by David White (17) and the senior writer for those organic sediments that are high in bituminous constituents.

Among other terms for lacustrine sediments that have been used are dy, förna, äfja, and gyttja (Wasmund, 1930). Dy is defined by Naumann (1931) as the chief deposit of extremely humic waters (Hauptablagering der extremen Humusgewässer). It has been interpreted by the writers as applicable to organic sediments of colloidal dimensions and largely of allochthonous origin.

Förna is composed of little altered plant and animal remains, as leaves, stems, *et cetera,* which are in a transition stage to humus. Förna may be deposited on the land and in water and the organic materials have not been extensively changed. The materials may have grown at the places of deposition or the whole or a part may be allochthonous. The plant and animal remains are dominantly composed of what have been designated stable protobitumins, as cuticles, spore exines, stable waxes, cellulose, hemicellulose, lignin, pectin, and chitinous substances. Förna is the intial stage in the formation of sapropel as defined by Wasmund (1930).

Äfja is largely composed of unstable protobitumins, as the majority of organic fats, oils, proteins, *et cetera.* Deposits are made beneath water and are very extensively composed of planktonic organisms living in overlying waters, together with remains of other organisms living on the bottom and with or without admixed detrital particles and allochthonous other organic materials. The planktonic materials may be excellently preserved. There are all transitions between äfja and förna and between each of them and dy. Äfja is the initial stage in the formation of gyttja.

Sapropel is defined by Wasmund (1930) and Naumann (1931) as the end stage of förna from which it has been formed by necrobiologic or bacterial processes under dominantly reducing conditions. Sapropel is amorphous, original organic substances have been largely destroyed, and the color is generally black; only rarely is the color brownish. Texturally, sapropel is flocculent and sticky; it may be slippery and soapy. An odor of H_2S may be present.

Gyttja is formed from äfja under conditions which are largely oxidizing. Alteration from äfja is largely done by coprogenic processes although biogenic processes may not have been absent. Gyttja has been defined as a coprogenic thanatocoenose. It is generally of a brownish color; occasionally it is grayish or greenish. The texture is crumbly or fibrous.

Since there is an extremely wide range in the organic deposits of

lakes, there would seem to be considerable difficulty in stating which of the terms defined above should be used. As a general term for the organic deposits of lakes the writers and others have used the term sludge. This use has been criticized by Deevey (1929) as carrying the connotation of sewage pollution. That may be true, but the writers nevertheless consider the term an excellent one, and consider that its use conveys the correct implication that the sediment carries a high content of more or less unrecognizable organic matter. Moreover, it is not improbable that large parts of sludge are excremental. The terms "coarse-detritus ooze" and "fine-detritus ooze" by Deevey, are objectionable as the term ooze carries the connotation that numerous small shells are present. In addition, the term detritus refers to rock particles and should not be used for organic matter. The terms anthraxylon and attritus of Thiessen (12) are applied respectively to the recognizable and unrecognizable constituents of coals and they evidently represent the lithified equivalents of gyttja, sapropel and dy.

Some lakes have the sludge largely composed of a pale yellow transparent jelly-like substance which is colored to a greater or less extent by the presence of other constituents. This was found to have a thickness of at least 8.7 meters in Grassy Lake. This sludge is over 90 per cent water.

The thickness of the sludge has been measured in some lakes in northern Wisconsin and found to range up to 6 meters in Lake Nebish, Little John, and Scaffold and more than 11 meters in Grassy Lake. Although sludge has a somewhat definite surface, it does not form a firm bottom as much of it has little more consistency than water. It offers little resistance to falling particles of sand or gravel dimension and in one sense can not be considered the bottom.

Hard-water lakes are likely to contain marl or carbonate deposits among which diatoms may be common to rare constituents. They may also contain sponge spicules. Soft-water lakes contain little or no carbonates, and if protected against entrance of inorganic sediments, they may have diatoms, spicules, pollen, and other sediments of organic origin as the most important components.

The calcium carbonate of the sludge of hard-water lakes seems to contain few shells. Most is in the form of microscopic crystals of calcite and aragonite. However, the marl deposits of Lake Wingra, a small lake at Madison, Wisconsin, contain large numbers of the shells of several small gastropods. The sludge so far studied in the lakes of Wisconsin contains little or no magnesium and crystals of magnesite or dolomite have not been seen. Other constituents of sludge are inorganic materials, as sand, silt and clay, the proportions varying from

place to place and from time to time. Some of the sand particles are large. Soft-water lakes at the other extreme contain little or no calcium carbonate but do have some combination of the other constituents.

Under some conditions that are not well understood, nodules and crusts of iron and manganese oxides are precipitated on lake bottoms. The two oxides occur together and the structure of the deposits is concretionary. Deposition takes place on the top and sides of particles of rocks in the range from pebbles to boulders or it may take place to form a crust over a part of the bottom surface. Various other substances of organic and inorganic origin are in the nodules and crusts and these may be of greater quantity than the iron and manganese oxides. Lakes of which the bottoms are covered with sludge do not seem to have concretionary deposition of iron and manganese and they also seem to be wanting on bottoms composed of calcium carbonate. Bottoms on which deposition of the two oxides takes place seem to be places of slow deposition of other sediments. Bacteria are thought to be responsible for the deposition. Iron and manganese oxide crusts have been dredged in Trout Lake, Vilas County, Wisconsin, to depths of 22 meters.

With progress downward the sludge becomes more compact, contains less water, generally has lighter color, contains less organic matter and correspondingly greater quantities of other constituents. These sediments are thought to have had originally the same characteristics as those at the top.

RATES OF DEPOSITION IN LAKES

There is little information respecting rates of deposition. Attempts have been made to learn rates, but results have not been encouraging. There are many factors on which rates of deposition depend, and it is thought that whatever may be learned would have application only to the place in the lake concerned as long as the conditions did not change. It is thought that Crystal Lake in northern Wisconsin, a lake containing soft water, surrounded by excellent vegetable protection and receiving surface inflow through swamps from areas of little relief, has not received more than 2.5–3 meters of sediment since the disappearance of the Wisconsin glaciers, approximately 25,000 years ago. As the sediments concerned are more than three-fifths water, this thickness on compaction would decrease to a meter or a little more. This gives a rate of deposition of about 1 meter in 25,000 years, or about a foot in 8,000 years.

The sediments in the deeper waters of Nebish Lake in northern Wisconsin, a lake also containing soft water, situated in glacial out-

wash of considerable relief and surrounded by excellent vegetable protection, were found to be 4–5 meters in thickness, and as these sediments in their present state are at least three-fifths water, the thickness on compaction would decrease to approximately 1.5–2 meters of sediment. These sediments were deposited since the disappearance of the Wisconsin glaciers, 25,000 years ago, giving a rate of deposition of about one foot in every 4,000–5,000 years. On the other hand, Lake Mendota, a hard-water lake in southern Wisconsin, is thought to have 30 feet of marl, about 10 meters, deposited over its deep bottom (depth of about 24 meters) in the same period of time. This gives a rate of deposition 3–4 times as great as that in Nebish Lake and 4–5 times as great as that in Crystal Lake. There probably is no characteristic rate of deposition.

CHANGES IN LAKE SEDIMENTS AFTER DEPOSITION

The nature of the changes that take place in lake sediments after deposition has been little investigated despite the great importance of this problem. A few facts are known and these serve as basis for suggestion of other changes. Changes seem to be more or less intimately connected with the work of bacteria, fungi, and other micro-organisms. Bacteria are known to form ammonia (NH_3), nitrogen oxide (NO_2), hydrogen sulphide (H_2S), methane (CH_4), and some, apparently the most numerous bacteria in the sludge of lakes, are the decomposition bacteria that form water and carbon dioxide. It is believed that some bacteria precipitate calcium carbonate, that the ammonia formed may ultimately result in precipitation of calcium carbonate and perhaps calcium phosphate, that the hydrogen sulphide may lead to formation of ferrous and ferric sulphides, that the carbon dioxide formed in decomposition leads to solution of some calcium carbonate, and that certain bacteria may be responsible for formation of hydrocarbons from cellulose, lignin, and the fats, waxes, gums, and resins of organic matter. These activities and processes are discussed in some detail.

The sludge on the bottoms of lakes Monona and Mendota, two hard-water lakes with eutrophic waters on the bottom and situated in southern Wisconsin in the midst of dolomitic limestones and dolomite-cemented sandstones, is very black and averages more than 1 million anaerobic and more than 15 million aerobic and facultative bacteria per gram of dry sludge. These figures represent the total bacterial flora of all kinds. The organic matter in the sludge covering the bottom of Lake Mendota may be as great as 50 per cent. Samples of the firm sediments beneath the sludge (still averaging more than 60 per cent water) have an organic content of 10 or less per cent, and

at a depth of 2–3 meters the sediments are almost white. The calcium carbonate of 10 samples of sludge from Lake Mendota averages 26.4 per cent and of 13 samples of the firm deposits beneath the sludge the average calcium carbonate is 73 per cent. The color of the surface sludge is black and it becomes progressively lighter in color with depth. The change in color and the increase in calcium carbonate and other inorganic constituents with depth are due to the work of bacteria. Sediments from Crystal Lake, a soft-water oligotrophic lake of northern Wisconsin with little or no carbonate in the sediments, has an average of 51.3 per cent organic matter (loss on ignition considered organic matter), but only 8.17 per cent at a depth in solid fine-grained sediments approximately 2.5 meters beneath the bottom.

What seems to be taking place is elimination of organic matter by decompositional bacteria. This results in change of color and production of carbon dioxide. The carbon dioxide thus produced should bring about solution of carbonate and concentration and percentage increase of silica, alumina, and ferric hydroxide in the sediments that remain. This would no doubt be the case if calcium carbonate were not reprecipitated by some other agency. Such reprecipitation seems to take place. If reprecipitation did not take place, originally organic-rich calcareous sediments would ultimately change into deposits of silica, aluminum silicates, and ferric hydroxide. This may locally take place. The dissolved calcium carbonate could very readily be removed by a current unsaturated with calcium carbonate moving over the bottom as was described for marine bottoms by Correns (3). As already noted, the calcium-carbonate content of the sediments of the two hard-water lakes studied increases with depth, also, as previously explained, decompositional bacteria are producing carbon dioxide which is dissolving calcium carbonate so that there should be a decrease with depth unless some agency is reprecipitating the carbonate.

It has been suggested that deposition and preservation of fine calcium-carbonate sediments is not likely in lake waters of any depth due to the saturation of the waters of the hypolimnion with carbon dioxide (7, 1925). What the limiting depth is, if any, has not been determined. It probably varies with different lakes due to variations in quantity of calcium carbonate precipitated. Two hard-water lakes of Wisconsin have been studied by the writers, Lake Mendota and Lake Monona, and calcium-carbonate deposits have been found to a depth of 24 meters beneath water level in Lake Mendota. This is the greatest depth in the two lakes. The calcium carbonate beneath the deep bottom of Lake Mendota is about 10 meters thick so that carbonate deposition in this lake took place to a depth of 34 meters. Green Lake has been

studied by the Wisconsin Biological Survey and fine calcium-carbonate sediments cover the deepest bottoms of this lake. This is more than 70 meters.

It is believed that the bacteria are responsible for the reprecipitation of the calcium carbonate. Williams and McCoy (19, 1934) have shown that there are aerobic bacteria in the sludge and the underlying sediments of Lake Mendota, and, by inference, in the sediments of other hard-water lakes, that precipitate calcium carbonate under laboratory conditions and that some of them precipitate calcium carbonate from solutions of the same degree of saturation as in the waters of the sludge from Lake Mendota. The carbonate precipitated in the Williams and McCoy experiments was calcite as determined by X-ray analysis. Sludge in containers submerged on the bottom of the lake did not change in carbonate content during the period of observation. This may have been due to equilibrium relations between production of carbon dioxide, solution of calcium carbonate, and formation of calcium carbonate. Only as production of carbon dioxide declined could precipitation of calcium carbonate be expected to exceed its solution.

The sediments contain ammonia-forming bacteria. The ammonia probably unites with the carbon dioxide formed in decomposition to produce ammonium carbonate. This may react with any calcium sulphate in solution to precipitate calcium carbonate as shown in the equation: $(NH_4)_2CO_3+CaSO_4=CaCO_3+(NH_4)_2SO_4$.

This reaction is not likely to take place to any great extent in most fresh-water lakes because of the limited quantity of calcium sulphate in solution. It may be a common reaction of the lakes of regions which receive waters from streams that drain terranes containing calcium sulphate, as, for instance, the western plains region of the United States. Another reaction that is more likely to take place is that between ammonia and calcium bicarbonate, as shown in the equation: $2(NH_4OH)+H_2Ca(CO_3)_2=(NH_4)_2CO_3+2(H_2O)+CaCO_3$.

It is not known whether the precipitation of calcium carbonate observed by Williams and McCoy was due to some reaction indirectly connected with bacterial activity, or the bacteria precipitated the calcium carbonate directly, perhaps by utilization of carbon dioxide of the calcium bicarbonate for food. It is thought that, as results of decomposition of organic matter and production of carbon dioxide by one group of micro-organisms with solution of calcium carbonate and precipitation (either directly or indirectly) by another group, the quantity of calcium carbonate in a sediment under some conditions remains essentially constant, under other conditions it increases, and

under still others—where there are currents to carry the carbonates away—it decreases. On the bottom of a deep hard-water lake like Lake Mendota, removal is not likely and the actual quantity of calcium carbonate may be expected to remain the same or increase, either condition bringing about a percentage increase.

The ammonia may also lead to the precipitation of calcium phosphate as the ammoniacal solutions may dissolve phosphatic constituents from exoskeletons, shells, and bones, and ultimately precipitate the phosphate as nodules or coating.

Some hydrogen sulphide is known to be formed. This may have formed from organic matter in the sediments or from reduction of sulphates in solution. In either case bacteria are thought to be responsible. The hydrogen sulphide may react with ferrous salts in the sediments, or in solution in the waters, to form the black ferrous sulphide, hydrotroilite, which in course of time changes to marcasite or pyrite. The ferrous salts may be original constituents of the sediments or they may have been produced through reduction of ferric hydroxide under anaerobic conditions.

Thus, as a result of changes after deposition, an original deposit may lose all contained organic matter, may lose all contained calcium carbonate, may have an increase of calcium carbonate, may change ferric hydroxide to ferrous carbonate and this may change to ferrous or ferric sulphide. An organic-rich sediment may become an organic-poor sediment. Original calcareous sediments may become a limestone, a diatomite, or a mudstone, depending on whether or not the carbonate is increased, remains the same, or is removed. If decreased, the residue is either a mudstone or a diatomite, depending on original composition. Diatom tests are rather consistently present in lake deposits of the upper Mississippi Valley and in the sediments of protected soft-water lakes, they may compose a half or more of a deposit, exclusive of organic matter.

If conditions are such as to prevent, or almost prevent decomposition of organic matter, lithification produces a calcareous or a non-calcareous black mudstone, or a calcareous or non-calcareous peat.

As previously noted, plant materials consist of proteins, cellulose, lignin, fats, waxes, gums, and resins. The decomposition is selective, the more desirable substances from the point of view of the bacteria being eliminated first. Such elimination increases the percentage of the fats, waxes, gums, resins and lignin and it may change a substance in which these substances constitute but a small percentage into one in which they predominate. A carbonaceous organic substance may become a bituminous one, and thus on lithification form an oil shale

or cannel coal depending on the percentage of inorganic materials.

Thus a non-calcareous sludge may form a light-colored mudstone, a diatomite, a black carbonaceous or bituminous mudstone, or a cannel coal. A calcareous sludge may produce a limestone, a diatomite, a light-colored shale, a calcareous dark shale, or a calcareous cannel coal.

Analyses of the sediments of lakes so far studied have shown that some of them contain gas, oils, and wax. Gas was observed escaping in large quantities from the sediments of Lake Allequash and Grassy Lake. It was caught in wide-mouthed glass jars and exploded readily when ignited. It was judged to be methane. The oils and wax were extracted with ether and chloroform and the quantities obtained were found to range to as much as 20 gallons per ton of dried sediments. The sources of the oils and wax are thought to be in diatoms, fatty algae, animals, and perhaps some of the higher plants. Some may have been formed from bacterial decomposition of non-fatty organic matter. The character of the oils is not known. The character of the wax was determined by Professor V. W. Meloche of the department of chemistry of the University of Wisconsin who reports that

> The material is insoluble in water, HCL, KOH, and cold concentrated H_2SO_4. It burns with a yellow, non-smoky luminescent flame and leaves only a slight carbon residue on ignition. The color of bromine water and dilute KMn_4 is discharged slightly when these reagents are added to a solution of the material on CCl_4, indicating the possible presence of a small amount of unsaturated substances.
>
> The solid material melts at 50–55°C. When mixed with sulphur and heated to above 200°C., H_2S, is liberated readily.
>
> The material is a *paraffin wax*, possibly the naturally occurring "ozokerite" with slight traces of higher unsaturated hydrocarbons. Further characterization would be a rather extended job.
>
> Please note that the absence of a strong test for unsaturation is not particularly significant. The samples have been exposed to air for some time and the samples could have changed considerably in this respect.

The writers consider these results significant as they show that both gaseous, liquid, and solid hydrocarbons are forming in the lake sediments (9).

STRATIFICATION OF LAKE SEDIMENTS

The view has long prevailed that the fine sediments of lakes are excellently stratified in thin units. Probably partly responsible for this view is the fact that colloidal sediments entering fresh-water lakes are not likely to be immediately, if at all, flocculated, and thus may be expected to settle slowly, and to the fact that the sediments

deposited in glacial lakes of the present that have been studied are splendidly varved and laminated, and also the excellent lamination in the Green River shales, generally considered to have been deposited in a lake. However, the fine sediments of not a single one of the lakes so far studied show lamination, or stratification of any degree of perfection. This may be due to the fact that the sediments studied contain a large content of material of organic origin. Sands about the beaches and beneath the adjacent shallow water are stratified and in many cases more or less excellently laminated, but this is not the case in fine sediments that contain organic matter. No lamination was seen in the deep-water deposits of any one of the 8 lakes so far carefully studied and the observations extend to depths of 3–8.7 meters. Whittaker (18) found stratification in McKay Lake, a small body about 500 yards long and 200 yards wide, near Ottawa, Canada. Kindle has noted some deep-water lamination (7, 1927), and the senior writer has seen some stratification, not good, in a post-Wisconsin marl deposit now beneath a swamp near Montello, Wisconsin. Some of the lamination observed by Whittaker was excellent. It was seen in a layer of chocolate-brown ooze with a thickness of 9.5 inches. This contained 440 double laminae, each consisting of one gray and one chocolate unit, each about equal thickness. Each double lamina—a varve—was about 0.017 inches thick.

The absence of lamination and stratification is due to several causes. Deposition on deep bottoms, or bottoms protected against clastic sediments in considerable quantities, is essentially continuous. The sludge is soft and inorganic materials of any degree of dimension are not deposited on top of it, but sink to depths determined by their dimensions and the increasing consistency of the sludge with depth, and the sludge and the underlying deposits are continuously being worked over by organisms which more or less knead the deposits, thus preventing or destroying lamination.

SUMMARY

Sediments of lakes at times of lithification may be calcareous with a range of organic matter from little to much. The calcareous sediments contain a range in siliceous materials (partly diatomaceous) from small to large, and some argillaceous matter may be expected. Argillaceous sediments may be organically rich to organically poor, calcareous or non-calcareous, and there is usually a content of diatoms. Sediments may be arenaceous with or without a small content of organic matter, with or without a calcareous or argillaceous content, and in the range from sand to boulders. They may also be car-

bonaceous or bituminous with some content of argillaceous, calcareous and siliceous (partly diatomaceous) matter.

They are rarely stratified over the deeper parts of the basins. Absence of stratification is referred to reworking by organisms.

The sediments after deposition may undergo little to extensive diagenetic changes. Organically rich sediments may change to organically poor sediments. The carbonate content of calcareous sediments may more or less entirely disappear and a sediment which in the beginning would produce a limestone may change to one that produces a diatomite or a mudstone. A calcareous sediment may also increase in quantity of carbonate. Bacteria and fungi are held as the most important agents in producing these changes. Organically rich sediments produce an inflammable gas which is considered to be methane and some processes lead to the formation of oil soluble in ether and chloroform and a wax, identified as paraffine.

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LABORATORY AND FIELD OBSERVATIONS OF EFFECT OF ACIDIZING OIL RESERVOIRS COMPOSED OF SANDS[1]

P. E. FITZGERALD,[2] J. R. JAMES,[3] AND RAY L. AUSTIN[4]
Tulsa, Oklahoma; Midland, Michigan; Casper, Wyoming

ABSTRACT

The widespread use of chemicals on oil and gas reservoirs composed of limestones has attracted the attention of engineers and geologists to the many wells producing from sands. The early attempts to treat wells producing from sands were not uniformly successful. During the past several years the writers have been collecting cores from various producing formations; most of them have been studied in the laboratory. In certain areas chemicals have been used on sands with good results. This paper discusses the results of the laboratory work and contains a compilation of well-treating data. Of the more than 300 cores studied, more than 80 per cent showed an increase in permeability when acidized in the laboratory. The average permeability increase was more than 300 per cent. The average acid solubilities of the more than 80 different oil-producing sands was 8.5 per cent.

The writers have also included data on compressive strength of the cores before and after acidizing and chemical and X-ray analyses of typical sands.

The present highly developed status of the oil industry is the result of well trained petroleum technologists who have been responsible for the development of more efficient and economical methods of exploration, drilling, production, and refining. As a result, new oil reserves have been discovered, field operations are more efficient, finished products are better and cheaper. An important part of this program has been the laboratory and field research on methods for increasing well efficiency and recovery of a greater percentage of the oil contained in the reservoir.

One of the methods that has a direct bearing on this phase of the oil industry is acidizing. This method became a recognized part of well completions and work-overs in nearly all fields where the oil and gas are produced from limestone and dolomitic formations soon after Grebe and Sanford[5] applied inhibitors to prevent acid corrosion of the well equipment.

Acidizing of a well results in a permanent physical change in the reservoir rock so that pressure differentials across a portion of it are reduced, thereby permitting a more efficient utilization of the available energy. Thus, a given unit of energy is able to move a greater volume of oil through the rock into the well. Actually the acid used

[1] Manuscript received, October 5, 1940.

[2] Research geologist, Dowell Incorporated.

[3] Research chemist, The Dow Chemical Company.

[4] District manager, International Cementers, Inc.

[5] U. S. Patent 1,877,504 (September 13, 1932).

dissolves a portion of the producing formation, allowing it to be removed in liquid form. The result of the acidizing process is both to enlarge the diameter of the well and to enlarge and open the pores in the formation. However, mathematical and theoretical considerations indicate that merely enlarging the diameter of the well will not secure the large production increases so often obtained by acidizing. More often the production increases can be most reasonably explained as resulting from the removal of pore-blocking and fracture-filling material.

With the widespread use of the acidizing process on reservoirs composed of limestone, it was only natural that attention should be attracted to the many thousands of wells in sandstone formations which produce a large percentage of the petroleum in the United States. Some of these wells in the proximity of established acidizing stations were given acid treatments for experimental purposes just to learn whether this new tool of the production engineer might not also be applicable to wells producing from sandstones. On these early treatments the same technique was used as had been proved successful on wells producing from limestones. As might have been anticipated, a large number of the treatments were failures, yet some of them responded with good increases in production. It was, then, a case of trial and error to determine in which areas such wells could be treated. By this uncertain method of selection a few areas were found in which satisfactory treatment responses could be obtained and a number of very profitable treatments were made.

In the acidizing of sandstone formations, the percentage of soluble material is by no means a criterion by which possible success of a treatment may be predicted. As a matter of fact, in some instances better results have been obtained in sandstone formations containing low percentages of acid-soluble material than in those containing comparatively high amounts of soluble material.

Laboratory testing of core samples from the producing formation prior to treatment usually gives a good indication of whether a satisfactory production increase can be expected from acidizing. The usual tests made on sandstone cores, that is, porosity, permeability, oil saturation, acid solubility, and chemical analysis, generally do not indicate with any degree of certainty the results to be expected from acidizing. Therefore, additional tests have been devised which have a more direct bearing on the behavior of formations when they are acidized. The most important of these tests are determination of permeability before and after acidizing the core in the laboratory, and determination of the compressive strength of the rock before and after

acidizing. The procedure used in making these tests is described in detail in another section of the paper.

This paper is in the nature of a progress report containing tabulated data and discussion of the laboratory work on a group of cores collected for acidizing studies. They were taken from various oil-producing sands ranging in age from the Ordovician to the Miocene. The cores were taken from the producing section only, a factor which limited the work and narrowed the geographical and geological ranges of the investigation.

The field and laboratory work is being continued on other phases of the problem with special attention being given to high-pressure chemical experiments, thin sectioning, screen analysis, and spectrographic studies. It is believed that the program under way will reveal more about the character and manner of the occurrence of the cementing material and the effect of the various treating agents upon the oil-producing formations.

No discussion is included in this paper on those acid mixtures known as Mud Acid now being used rather extensively on the Gulf Coast and to a lesser degree in other areas to dissolve both carbonates and kaolin-type materials that may be present in the well due to rotary completion or indigenous to the formation. The application of these special acid mixtures has been singularly successful in the treatment of a large number of wells. However, this subject has been discussed fully in previous publications.[6,7,8]

It is hoped that the facts recorded here are significant and that they may be helpful to others studying the problem or related problems.

Various tests and analyses have been made on more than 300 diamond-drill cores. Of these, more than 80 per cent showed an increase in permeability when acidized in the laboratory; the average increase for all the cores studied was more than 500 per cent. Compressive strength tests have been made on cores to determine the loss in structural strength resulting from acid treatments in the laboratory. It was found that the loss ranged from 4 per cent to 77 per cent; the average for the entire group was 40.9 per cent.

The average acid solubility of the 90 different oil-producing sandstones analyzed was 8.5 per cent, a figure which agrees surprisingly

[6] H. L. Flood, "Acid Treatment of Sand Wells Revives Production," *Petrol. Eng.* (February, 1940), p. 170.

[7] S. C. Morian, "Removal of Drilling Mud from Formations by Use of Acid," *Petrol. Eng.* (May, 1940), pp. 117–20.

[8] *The Acidizer* (House Organ, Dowell Incorporated), Vol. 4, No. 3 (1940).

well with the data[9,10] of others since several different methods for determining them were employed.

METHOD OF STUDY

Preparation of cores.—Except in special cases, cores one inch in diameter were cut from the field sample. Half-inch cylindrical cores or rectangular blocks were prepared from the smaller field samples which were not large enough to permit cutting cores of the regular size. Usually the cores were taken in such a manner that the flow of fluid through them would be parallel with the bedding plane. After taking the desired number of diamond-drill cores, a portion of the remaining sample was used for other phases of the study, including solubility in hydrochloric acid, chemical and X-ray analyses, and the preparation of petrographic thin sections. The balance of the field sample was stored for future checking and study.

Preparatory to the analyses, the small cores were refluxed in an ether-acetone solution for 10–12 hours. Occasionally additional extracting with carbon tetrachloride or benzene was necessary to remove the oil or wax adhering to the cores. After extraction, the cores were dried in an electric oven at 100°C., following which they were cooled and stored in a desiccator until the various determinations could be made. The cores which had been acidized were also cleaned by extraction and dried before measuring the final permeability and porosity.

Porosity determinations.—Two methods of determining the available pore space of the small cores have been used, the Barnes[11,12] method and a gas-expansion method employing a Stevens[13] porosimeter. The latter method with a modified apparatus is now used almost exclusively. The core chamber of the Stevens porosimeter has been changed in order to facilitate inserting and removing cores without lowering the mercury reservoir and subsequently the level in the calibrated tube. It is estimated that this modified porosimeter requires about 25 per cent less time to operate.

The modified chamber is essentially a ground-glass joint containing a vent. The cores fit snugly into the plug or male member, having a

[9] W. H. Twenhofel, *Treatise on Sedimentation* (1932), p. 3.

[10] Parker D. Trask, "Calcium Carbonate Content of Some California Mesozoic and Tertiary Sediments," *Bull. Geol. Soc. America*, Vol. 49 (August 1, 1938), pp. 1169–82.

[11] G. H. Fancher, J. A. Lewis, and K. B. Barnes, "Some Physical Characteristics of Oil Sands," *Pennsylvania State College Bull. 12* (1933), pp. 66–80.

[12] K. B. Barnes, "Porosity and Saturation Methods," *A. P. I. Drilling and Production Practice* (1936), pp. 191–203.

[13] A. B. Stevens, "Determining Porosity by the Gas Expansion Method," *A.I.M.E. Petrol. Tech.*, Vol. 11, No. 2 (May, 1939). *T. P. 1061.*

straight inner wall and tapered outer wall, which is inserted into the female member. The vent is open when the plug is inserted allowing atmospheric conditions to exist when the chamber is sealed. The sealing is accomplished by turning the plug one-half revolution. After measuring the air volume, the plug can be withdrawn by turning it until the holes in the outer and inner wall coincide. Figure 1 illustrates the modified apparatus used in this work.

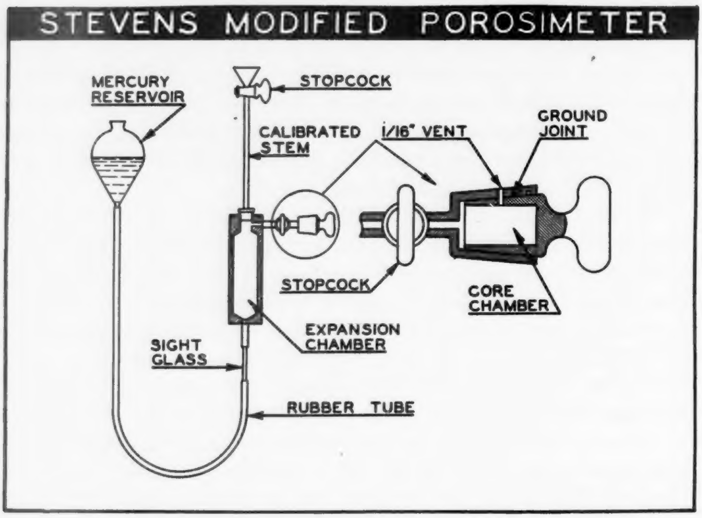

FIG. 1

Except for the rubber tubing, glass has been used throughout in the construction of this apparatus. However, it has been securely mounted on a board which facilitates its operation and has the additional advantage of making the apparatus less readily breakable.

Permeability measurements.—The apparatus used in this work is essentially the same as that used by Pyle and Sherborne.[14] The rate of air flow through the cores is proportional to the readings on the differential manometer of a flow meter. Turbulent flow through the cores is prevented by the back pressure created by the flow meter. The time for individual calculations has been shortened by the construction of curves and tables for various differential pressures. However, necessary corrections must be made for temperature and barometric changes.

[14] H. C. Pyle and J. E. Sherborne, "Core Analysis," *A.I.M.E. Petroleum Development and Technology*, Vol. 132 (1939), pp. 33–61.

Solubility determinations.—Several methods have been used to determine the solubility of the samples in hydrochloric acid. A rapid method of approximating the acid-soluble portion is to measure the volume of gas evolved from the reaction of the acid on a weighed sample of pulverized material. From this measured volume of gas, the carbonate content can be calculated. However, the determinations made in this manner do not include the soluble non-carbonate minerals, such as the iron and aluminium compounds, which are commonly present in oil-bearing formations as cementing or pore-filling material.

More accurate determinations of solubility can be made by the gravimetric method,[15] titration method,[16] chemical analysis,[17] and the gravimetric method in which a Gooch crucible is used.[18]

TABLE I

AVERAGE CHEMICAL ANALYSES OF OIL SANDS

State	Formation	Number of Samples	Percentage							
			Acid Insoluble	R_2O_3	CaO	MgO	Fe	Al	SO_4	CO_2
California	Miocene	6	89.2	4.01	2.44	1.10	1.6	0.97	0.011	4.4
Wyoming	Wall Creek	9	94.9	1.51	1.11	0.90	0.46	0.48	0.070	1.22
Wyoming	Sundance	1	91.3	0.41	4.13	0.11	0.17	0.10	Nil	3.02
Wyoming	Leo	4	44.1	0.38	14.66	7.90	0.11	0.13	5.55	17.70
Oklahoma	Bartlesville	1	91.9	4.61	0.80	0.86	1.14	1.84	0.003	1.32
Oklahoma	Calvin	1	87.1	2.08	3.70	1.59	1.31	0.41	0.004	4.71
Oklahoma	Senora	1	83.6	5.27	0.18	1.19	2.01	1.27	0.020	1.52
Oklahoma	Boggy	1	88.1	2.08	3.15	1.63	1.13	0.50	0.005	2.10
Oklahoma	Allen	1	96.4	2.20	0.26	0.37	0.80	0.56	0.018	0.87
Oklahoma	Wilcox	1	96.4	1.45	0.97	0.30	0.64	0.42	0.015	0.87
Texas	Holt	1	94.2	2.06	1.00	0.30	0.61	0.63	0.076	2.07
Illinois	Bethel	3	72.8	1.37	0.49	0.43	0.36	0.65	0.015	5.9
Ohio	Berea	3	92.6	1.98	0.92	0.92	0.14	0.19	0.006	1.14
Kentucky	Corniferous	11	70.0	1.85	9.80	4.84	1.07	0.18	0.110	12.77

The gravimetric method employing the Gooch crucible is a fairly rapid and accurate method of determining the amount of soluble material in a sample for a given acid solution. The effect of temperature can easily be determined by this method. When this method is used a weighed sample of crushed material is digested in an excess of acid at the desired temperature. Upon filtering, the insoluble material is

[15] W. F. Hillebrand and G. N. F. Lundell, *Applied Inorganic Analysis*. John Wiley and Sons (1929), p. 623.

[16] R. K. Meade, *The Scott Standard Method of Chemical Analysis*, 4th edition (1925), p. 1223.

[17] W. W. Scott, *Standard Method of Chemical Analysis*, Vol. 1, 4th edition. D. Van Nostrand (1925), p. 596d.

[18] *Ibid.*

retained on the asbestos mat in the bottom of the crucible. After drying, the crucible is reweighed and the additional weight represents the insoluble material; from this, the amount of material dissolved is easily determined.

In the titration method the sample is boiled in a standard quantity of 0.4 normal hydrochloric acid and titrated with 0.2 normal sodium hydroxide to determine the amount of hydrochloric acid that has been neutralized. This method is not as reliable as the gravimetric method, but according to Trask[19] is ordinarily accurate if representative samples of the different types of sediments that are being tested are checked by the gravimetric method so that allowance can be made for the acid that is neutralized by the noncarbonate constituents of the samples.

Solubility of a rock sample can be determined from a complete chemical analysis. However, this method is expensive and much slower. The procedure used in this method is described in Scott's *Standard Method of Chemical Analysis*, 5th edition.[20] Table I shows some chemical analyses of typical oil-producing sands. These data give the average composition of the soluble portion of the sample. The percentage of the acid-soluble part of the sample can be determined by subtracting the figures in column 4 from 100 per cent. For example, the acid solubility of sample 1 was 10.8 per cent.

The X-ray can be used to approximate the acid solubility by identification of the soluble compounds present in the sample. The basis for chemical analysis by X-ray diffraction as stated by Hull[21] is,

> That every crystalline substance gives a pattern; that the same substance always gives the same pattern; and that, in a mixture of substances, each produces its pattern independently of the others, so that the photograph obtained with a mixture (of compounds) is the superimposed sum of the photographs that would be obtained by exposing each of the components separately for the same length of time.

These facts make this method available for determining the basic nature of the materials composing the core samples.

The sensitivity[22,23] of detection of a component will vary from

[19] Parker Trask and H. E. Hammer, "Preliminary Study of Source Beds in Late Mesozoic Rocks on West Side of Sacramento Valley, California," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 18, No. 10 (October, 1934), p. 1358.

[20] W. W. Scott, *op. cit.*, 5th edition. D. Van Nostrand (1939).

[21] A. K. Hull, "A New Method of Chemical Analysis," *Jour. Amer. Chem. Soc.*, Vol. 41 (August, 1919), pp. 1168–75.

[22] J. D. Hanawalt, H. W. Rinn, and L. K. Frevel, "Chemical Analysis by X-Ray Diffraction," *Ind. and Eng. Chem.*, Vol. 10, No. 9 (September 15, 1938), pp. 457–512.

[23] W. P. Davy, *Jour. Appl. Physics*, Vol. 10 (1939), p. 820.

1 per cent for a well defined, crystalline material like quartz to possibly 25 per cent or more for nearly amorphous materials such as some clays.

Figure 2 and Table II show some X-ray diffraction patterns of typical oil sands and the corresponding chemical analysis of each sample based on these patterns.

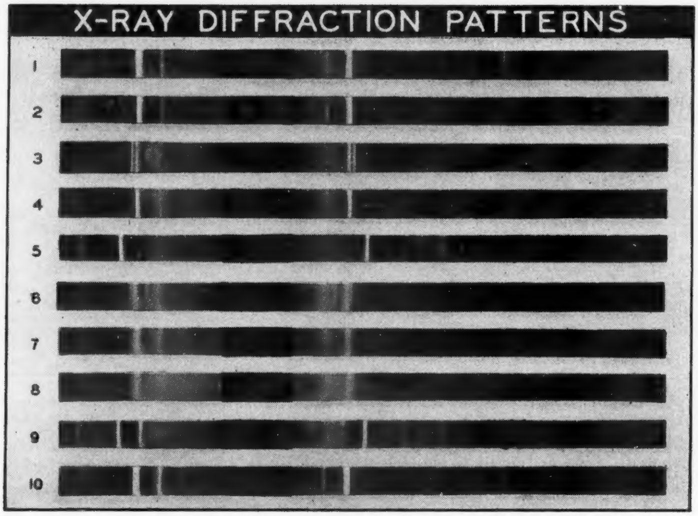

FIG. 2

TABLE II
X-RAY ANALYSES

No.	*Formation*	*Quartz*	*Dolomite*	*Anhydrite*	*Feldspar*		*Clay*	*Misc.*
					Albite	*Andesine*		
1	Benoist, Ill.	100						
2	3rd Leo, Wyo.	75	25					
3	Miocene, Calif.	40				60		
4	Peru, Kans.	70			20			10 Chlorite mineral
5	Arbuckle, Kans.	5	95					
6	Frontier, Wyo.	60				20	20	
7	Frio, La.	70			10		20	
8	Frio, Tex.	60			10		30	1 Pyrite
9	Permian, Tex.		60	40				
10	Gilcrease, Okla.	100						

Compressive strength tests.—In order to evaluate the effect which removal of acid-soluble material has on the strength of a core, compressive strength tests have been made on cores treated with acid and very similar cores which have not been treated. The usual procedure consists of taking a 1-inch × 2-inch cylindrical core from a field sample and cutting it into two 1-inch cores; these cores are carried through the same program—that is, refluxing and drying, measuring permeability, porosity, and solubility. One of each pair of cores is treated with acid. After determining the change in permeability and porosity, the strength of each core is tested on a Steel City strength-testing apparatus, the stress being applied parallel with the bedding planes.

The data in Table III shows the ranges in compressive strengths and the per cent loss effected by the acid treatment. Table IV contains a summary of all compressive strength data.

TABLE III

TYPICAL COMPRESSIVE STRENGTH DATA

State	Formation	HCl Sol. Percentage	Porosity Percentage		Permeability, Millidarcys			Compressive Strength Pounds per Square Inch		
			Before	After	Before	After	Percentage Increase	Before	After	Percentage Decrease
California	Lower Zone Cole's Levee	7.9	15.2	15.5	1.5	2.6	73	1,780	1,450	18
Illinois	Bethel	10	5.3	6.7	.509	.533	4	8,000	1,850	77
Oklahoma	Calvin	9.6	12.2	16.8	51	100	96	10,200	3,050	70
Oklahoma	Bartlesville	1.6	14.9	18.9	15.5	334	115	5,450	2,140	61
Oklahoma	Boggy	4.8	10.5	15.2	85.2	125	47	6,750	1,460	71
Oklahoma	"Wilcox"	0.8	0.5	18.4	60.3	35	42	8,800	2,550	71
Oklahoma	Allen	1.4	17.9	17.9	28.2	32.6	16	5,800	2,100	64
Kansas	Peru	0.4	15.5	20.5	3.9	44	1,030	5,000	1,750	65
Kentucky	Corniferous	20			8.2	65.2	700	4,930	2,920	41
Wyoming	Tensleep	8.4	12.6	13.7	68.4	36	47	13,550	2,560	81
Wyoming	1st Leo	14			.45	2.3	410	15,350	10,120	34
Wyoming	4th Leo	36			4	18	400	9,400	7,150	24
Wyoming	Basal Sundance				54	310	480	3,000	940	69

TABLE IV

SUMMARY OF COMPRESSIVE STRENGTH DATA

No.	State	Formation	Number of Cores	Average Strength Loss Percentage
1		Misc.	10	68.2
2	Wyoming	Leo	10	32.7
3	Wyoming	Sundance	7	40.6
4	California	Miocene	6	18.3
5	Kentucky	Corniferous	7	33.3
Totals			40	40.9

Acid treatment of cores.—After a core has been prepared for treating as previously described, it is placed in the beveled rubber core-holder

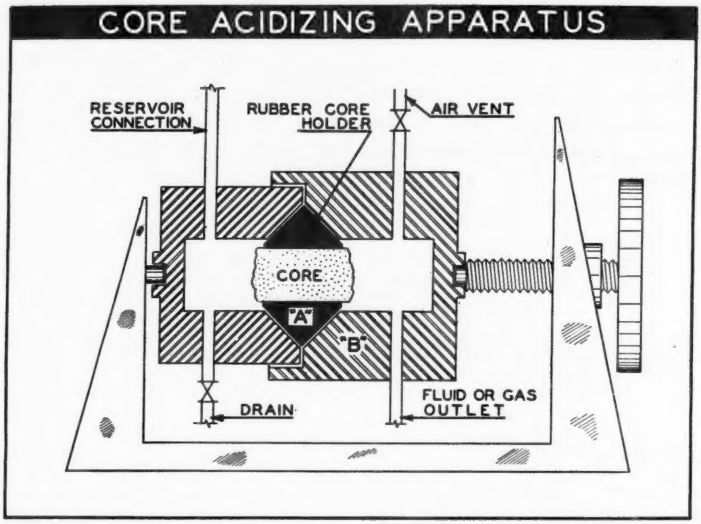
CORE ACIDIZING APPARATUS
RESERVOIR CONNECTION
RUBBER CORE HOLDER
AIR VENT
CORE
"A"
"B"
DRAIN
FLUID OR GAS OUTLET

Fig. 3

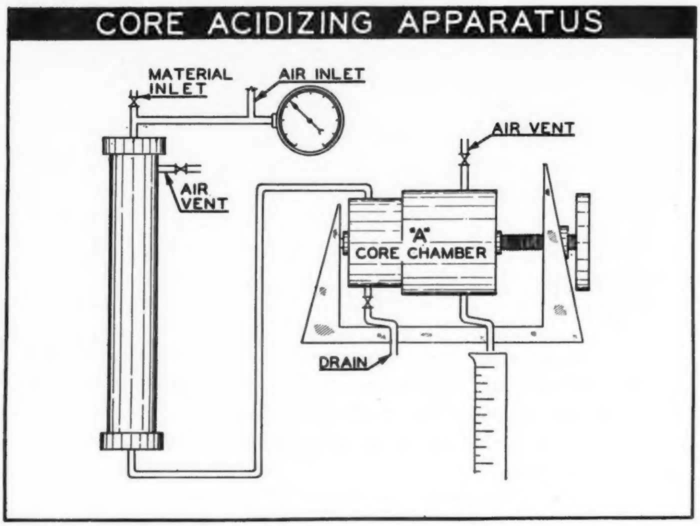
CORE ACIDIZING APPARATUS
MATERIAL INLET
AIR INLET
AIR VENT
AIR VENT
"A"
CORE CHAMBER
DRAIN

Fig. 4

illustrated at *A* in Figure 3. The assembly is then placed in the stainless steel core-holder shown at *B* in Figure 3 and clamped in place as shown in *A* in Figure 4. The acid is forced from the reservoir through the core at pressures dependent on the permeability of the core. The treating pressure, time of treatment, and volume of acid passing through the core are recorded for each core.

TABLE V

SUMMARY OF CORE-ACIDIZING DATA

State	*Formation*	*Number of Cores Acidized*	*Number Showing Permeability Increase*	*Number Showing Permeability Decrease*[a]	*Percentage Showing Permeability Increase*	*Average Percentage Permeability Increase*[b]
Pennsylvania	Bradford	11	10	1	91	175.7
Oklahoma	All sands	48	36	3	75	181.5
Oklahoma	Bartlesville	29	20	1	69	26.3
Oklahoma	"Wilcox"	6	4	1	67	995.0
Oklahoma	Boggy	7	6	1	86	49.3
California	All sands	58	36	17	62	526.0
California	Cole's Levee (Lower Zone)	23	14	6	61	492.0
Kentucky	All sands	27	26	1	96	630.0
Kentucky	Corniferous	22	22	0	100	645.0
Texas	Holt	11	10	0	91	99.3
Kansas	Peru	10	9	0	90	295.6
Wyoming	All sands	101	82	6	81	403.0
Wyoming	Tensleep	9[c]	8	1	89	1,134.0
Wyoming	Sundance	19	19	0	100	235.0
Wyoming	1st Wall Creek	6	4	0	67	5.9
Wyoming	2nd Wall Creek	12	5	0	50	56.0
Wyoming	Frontier[d]	32	25	5	78	55.0
Wyoming	Leo	13	13	0	100	174.0
Illinois	All sands	57	53	4	93	1,722.0
Illinois	Weiler	14	14	0	100	163.0
Illinois	Aux Vases	14	13	0	100	5,937.0
Illinois	Bethel	29	24	4	83	80.0
Michigan	Michigan Stray	9	8	0	89	40.0
Grand average					81.8	537.0

[a] Balance showed no change in permeability.
[b] Does not include cores that showed decrease in permeability.
[c] Does not include a core that channeled.
[d] Undifferentiated.

After the core has been treated it is removed from the holder, refluxed and dried, and subjected to permeability and porosity measurements to determine the effect of acidizing.

Various types of acids and addition agents were used in the studies described in this paper.

RESULTS OF STUDY

A summary of the core-acidizing study is contained in Table V. There are 332 cores from more than 30 different producing formations

included in this table. Of this total, 271, or 81 per cent, showed an increase in permeability when acidized in the laboratory. The average permeability increase was 537 per cent.

Most of the cores from Wyoming were taken from six different producing formations in four different fields. It is interesting to note that the average permeability increase for these formations is approximately 400 per cent, which is less than the average for all the sands studied. However, in spite of this smaller per cent permeability increase obtained in the laboratory, the best field results have been obtained in Wyoming. This may be partly explained by the fact that, in at least part of the wells treated in Wyoming, the formation con-

FIG. 5.—Core of Leo formation in Ohio Oil Company's Converse No. 8, Lance Creek field, Wyoming.

tains induced porosity which is probably the result of faulting. This type of porosity was evident in a core taken from the Leo sand at Lance Creek, illustrated in Figure 5. The rather unusual treating results obtained when formations of this type are acidized in the field may be due to the removal of the secondarily deposited acid-soluble materials that line or partly fill the small fractures. When the vein-filling material is removed large increases in porosity and permeability result with correspondingly large increases in fluid production. The phenomenon is well illustrated in Table VI. The extremely large permeability increases are not exhibited in the tabulation of the core data since efforts were made in the laboratory to avoid cutting cores containing veins filled with the highly soluble minerals. This procedure was followed in order to confine the studies to homogeneous material rather than material which would undoubtedly produce erratic data which would be difficult to evaluate.

TABLE VI

WYOMING WELL-TREATING DATA

County	*Field*	*Formation*	*Amount Acid*	*Production Barrels per day*		*Percentage Increase*
				Before	*After*	
Niobrara	Lance Creek	Leo (undifferentiated)	1,000	150	200	33
Niobrara	Lance Creek	Leo "	100	N.P.*	1,894	
Niobrara	Lance Creek	Leo "	5,000	55	138	151
Niobrara	Lance Creek	Leo "	3,000	150	250	33
Niobrara	Lance Creek	Leo "	1,000	384	421	12.2
Niobrara	Lance Creek	Leo "	1,000	N.P.*	75	
Niobrara	Lance Creek	Leo "	2,000	75	75	0
Niobrara	Lance Creek	Leo "	4,000	125	250	100
Niobrara	Lance Creek	Leo "	6,000	250	320	28
Niobrara	Lance Creek	Leo "	1,000	N.P.*	1,684	
Niobrara	Lance Creek	Leo "	1,000	N.P.*	1,920	
Niobrara	Lance Creek	Leo "	1,000	N.P.*	2,400	
Niobrara	Lance Creek	Leo "	1,000	N.P.*	1,440	
Niobrara	Lance Creek	Leo "	3,000	180	350	94.5
Niobrara	Lance Creek	Leo "	4,000	0	180	
Niobrara	Lance Creek	Leo "	6,000	180	300	66.7
Niobrara	Lance Creek	Leo "	2,000	N.P.*	980	
Niobrara	Lance Creek	Leo "	2,000	N.P.*	2,000	
Niobrara	Lance Creek	Leo "	1,000	N.P.*	4,217	
Niobrara	Lance Creek	Leo "	1,000	N.P.*	1,200	
Niobrara	Lance Creek	Leo '	2,000	N.P.*	7,800	
Niobrara	Lance Creek	Leo "	2,000	N.P.*	875	
Niobrara	Lance Creek	Leo "	1,000	N.P.*	433	
Niobrara	Lance Creek	Leo "	1,500	75	545	626
Niobrara	Lance Creek	Leo "	2,000	420	3,144	647
Niobrara	Lance Creek	Sundance	1,000	0	360	
Niobrara	Lance Creek	Sundance	2,000	120	361	200
Natrona	Salt Creek	1st Wall Creek	1,000	1	5	400
Natrona	Salt Creek	1st Wall Creek	1,000	2	20	900
Natrona	Salt Creek	1st Wall Creek	1,500	2	16	800
Natrona	Salt Creek	Sundance	1,500	2	8	300
Natrona	Salt Creek	Tensleep	1,000	25	62	148
Natrona	Salt Creek	Tensleep	1,000	6	168	2,700
Natrona	Salt Creek	Tensleep	1,000	N.P.*	91	
Park	Oregon Basin	Tensleep	1,000	150	250	66
Carbon	Medicine Bow	Sundance	1,000	8	300	3,650

* N.P.—No production test prior to acidizing.

Table VII contains the Wyoming core data developed in the laboratory.

Many samples were collected that were not used in the major part of this work. However, acid-solubility tests were made on this group of more than 600 samples representing 90 different oil-producing sands. The range of solubility and the average for each sand are shown in Table VIII. The average acid solubility for all sands was 8.5 per cent.

TABLE VII

SUMMARY OF WYOMING CORE DATA

Formation	*Number of Cores*	*Range*	*Average*
3rd Leo			
Solubility, %	5	14 – 66	44.2
Porosity, % (before)[a]	—		—
Permeability, M'd.[b] (before)	5	.4 – 18	6.8
Porosity, % (after)[c]	—		—
Permeability, M'd. (after)	5	8.4 – 101	38
Permeability increase, %	5	47 –1,900	887
Sundance			
Solubility, %	15	2 – 5.1	3.4
Porosity, % (before)	8	6.1 – 22	13.5
Permeability, M'd. (before)	20	0.2 – 350	95
Porosity, % (after)	—		—
Permeability, M'd. (after)	20	1.1 – 580	231
Permeability increase, %	20	7.7 –1,500	223
Wall Creek			
Solubility, %	18	.1 – 3.2	4.2
Porosity, % (before)	7	12.2 – 23.8	14.4
Permeability, M'd. (before)	15	0.3 – 200	58
Porosity, % (after)	—		—
Permeability, M'd. (after)	15	0.3 – 650	99
Permeability increase, %	15	0 – 550	47
Frontier			
Solubility, %	9	2 – 21.2	6.0
Porosity, % (before)	—		—
Permeability, M'd. (before)	26	0.6 – 400	118
Porosity, % (after)	—		—
Permeability, M'd. (after)	26	1.3 – 425	162
Permeability, increase, %	21	0 – 150	54
Tensleep			
Solubility, %	9	2.4 – 61	12
Porosity, % (before)	9	6.5 – 21.4	11
Permeability, M'd. (before)	10	0.15– 64.4	11.7
Porosity, % (after)	9	10.5 – 19.9	15.5
Permeability, M'd. (after)	9	.3 – 136.5	71
Permeability increase, %	8	4 –2,920	1,134

[a] Before treating.
[b] Millidarcys.
[c] After treating.

THEORETICAL CONSIDERATIONS

The theoretical considerations on the effect of permeability increase on the production of oil are somewhat complicated and involved due to the many variable factors that must be considered. However, if definite values are assigned to some of these variables, theoretical production increases can be determined.

TABLE VIII

ACID SOLUBILITIES OF PRODUCTIVE SANDSTONES

State	County	Formation	Acid-Solubility Percentage		
			Range		Average
Arkansas	Columbia	Jones	1.1	4.5	2.7
Arkansas	Union	Blossom	3.9	8.1	6.0
Arkansas	Union	Nacatoch	18.0	20.1	19.1
California	Santa Barbara	Capitan	0.4	2.0	0.7
California	Kern	Miocene	7.9	23.6	10.7
California	Kern	Cole's Levee Zone 2	4.5	23.5	6.4
California	Kern	Kettleman Hills	1.2	3.0	1.0
Colorado	Fremont	Pierre	23.6	63.0	30.8
Colorado	Moffat	Pierre	12.0	58.0	30.1
Colorado	Rio Blanco	Morrison	1.8	14.5	6.8
Illinois	Clark	Casey	2.4	15.7	13.7
Illinois	Clay	Aux Vases	1.4	8.2	5.7
Illinois	Crawford	Tracey	1.5	3.6	2.3
Illinois	Crawford	Bridgeport	2.5	8.0	5.4
Illinois	Fayette	Weiler	3.0	18.0	9.8
Illinois	Fayette	Bethel	3.0	14.0	9.6
Illinois	Fayette	Paint Creek	5.0	32.0	11.4
Illinois	Gallatin	Cypress	2.3	2.6	2.4
Illinois	Marion	Aux Vases	2.5	17.6	16.5
Illinois	Marion	Rosiclare	1.6	2.8	2.1
Illinois	Marion	Bethel	2.3	4.6	3.1
Illinois	Lawrence	Robinson	3.0	9.1	6.0
Illinois	Lawrence	Kirkwood	2.0	4.1	3.7
Illinois	Wayne	Aux Vases	2.6	62.7	29.8
Illinois	Wayne	Aux Vases	6.8	22.7	11.8
Illinois	Wayne	Aux Vases	5.5	23.5	11.7
Illinois	Wabash	Cypress	1.7	7.9	3.9
Illinois	Wabash	Cypress	29.3	41.3	35.3
Indiana	Gibson	Waltersburg	4.0	12.1	6.5
Indiana	Gibson	Tar Springs	5.0	13.0	9.0
Indiana	Gibson	Cypress	2.0	4.5	4.1
Indiana	Posey	Cypress	0.0	0.0	0.0
Indiana	Posey	Cypress	5.7	17.0	9.1
Indiana	Posey	Benoist	0.9	5.6	2.5
Indiana	Wabash	Brown	3.2	5.2	4.0
Kansas	Barton	Misener	10.0	40.0	21.0
Kansas	Chatauqua	Peru	0.4	10.8	3.1
Kansas	Greenwood	Bartlesville	1.6	2.1	1.7
Kansas	Russell	Reagan	1.0	3.0	2.0
Kentucky	Davies	Jett	1.0	21.0	11.2
Kentucky	Davies	Jones	2.3	11.1	3.5
Kentucky	Henderson	Jackson	12.5	16.1	13.8
Kentucky	Henderson	Barlow	3.0	26.1	5.1
Kentucky	Magoffin	Wier	1.2	2.1	1.6
Louisiana	LaFourche	Frio	3.3	81.0	4.1
Louisiana	St. Mary	Miocene	3.1	4.6	4.2
Oklahoma	Seminole	Gilcrease	0.1	12.0	5.4
Oklahoma	Hughes	Booch	0.1	2.0	1.9
Oklahoma	Numerous	Bartlesville	2.3	22.3	3.2
Oklahoma	Creek	Glenn	1.0	3.0	1.5
Oklahoma	Creek	Cleveland	1.7	2.0	1.8
Oklahoma	Creek	Dutcher	4.6	26.3	11.4
Oklahoma	Creek	Prue	1.9	17.6	9.7
Oklahoma	Kay	Tonkawa	2.1	3.3	2.4

TABLE VIII—*Continued*

State	*County*	*Formation*	*Acid-Solubility Percentage*		
			Range		*Average*
Oklahoma	Oklahoma	Jones	2.9	3.1	3.0
Oklahoma	Oklahoma	Kinter	1.3	4.6	3.2
Oklahoma	Oklahoma	Hammer	6.4	18.3	7.9
Oklahoma	Oklahoma	School Land	1.3	6.0	5.0
Oklahoma	Oklahoma	Burgen	1.9	2.0	2.0
Oklahoma	Osage	Burbank	2.1	7.3	6.4
Oklahoma	Osage	Tucker	4.7	4.9	4.8
Oklahoma	Osage	Skinner	5.0	20.3	6.3
Oklahoma	Osage	Squirrel	2.0	5.0	2.6
Oklahoma	Osage	Hominy	4.5	4.9	4.7
Oklahoma	Osage	Burgess	3.0	10.0	4.0
Oklahoma	Marshall	1st Bromide	1.8	47.5	21.0
Oklahoma	Jackson	Arkose	3.7	98.9	28.7
Oklahoma	Pottawatomie	Calvin	1.8	25.4	18.5
Oklahoma	Lincoln	Prue	1.6	3.1	2.7
Pennsylvania	McKean	Bradford	1.8	2.3	2.0
Pennsylvania	Tioga	Oriskany	2.0	3.0	2.1
Texas	Limestone	Woodbine	3.0	26.0	4.1
Texas	Montague	Holt	0.8	4.0	1.9
Texas	Montague	Arkose	3.3	7.1	5.1
Texas	Nueces	Frio	0.4	44.8	23.9
Texas	Liberty	Frio	0.9	9.3	3.0
Texas	Wharton	Kountz	N.M.*	1.4	1.0
Texas	Wharton	Lancaster	N.M.*	8.4	7.2
Texas	Brazoria	Frio	1.5	30.7	6.6
Texas	Baylor	Canyon	6.3	14.1	8.6
Texas	Wichita	Strawn	2.6	25.3	3.7
Texas	Montague	Strawn	1.1	1.8	1.2
Texas	Titus	Paluxy	0.1	67.0	23.0
Utah	Dagget	Dakota	1.1	1.5	1.2
Utah	Washington	Pennsylvanian	4.0	6.0	5.1
West Virginia	Roan	Big Injun	1.8	9.0	2.1
West Virginia	Roan	Keener	5.0	6.0	5.5
West Virginia	Kanawa	Squaw	1.0	2.0	1.6
West Virginia	Kanawa	Oriskany	5.0	16.0	7.8
West Virginia	Kanawa	Berea	1.0	1.5	1.2
West Virginia	Boone	Berea	1.0	1.8	1.2
Wyoming	Lincoln	Wasatch	4.6	18.8	12.2
Wyoming	Carbon	Tensleep	0.5	48.7	8.8
Wyoming	Weston	New Castle	9.0	28.3	11.4
Wyoming	Sweetwater	Sundance	6.1	9.9	9.0
Wyoming	Natrona	Tensleep	3.8	61.0	19.3
Wyoming	Natrona	Morrison	3.1	5.2	4.9
Wyoming	Natrona	1st Wall Creek	1.5	2.9	1.9
Wyoming	Park	Frontier	2.6	3.4	2.5
Wyoming	Park	Tensleep	1.4	3.1	2.0
Wyoming	Sublette	Wasatch	7.2	13.8	10.5
Wyoming	Natrona	2nd Wall Creek	1.1	4.5	2.7
Wyoming	Niobrara	Leo	7.8	10.5	8.7
Wyoming	Niobrara	Sundance	9.4	13.3	11.3
Wyoming	Carbon	Sundance	6.6	10.3	8.1
Wyoming	Carbon	Lakota	1.1	2.1	1.8
Wyoming	Carbon	Sundance	2.0	3.6	2.8

* Not measurable. Average solubility 8.5 per cent.

By assuming uniform initial porosity, permeability, and steady state of fluid flow, and using assigned values for permeability increases as determined from laboratory studies of cores taken from oil-producing formations, estimated increases in oil production can be calculated. Figure 6 illustrates theoretical production increases obtained when a sandstone with a uniform porosity of 20 per cent is acidized certain radial distances from a 6-inch diameter well. Each curve represents a different increase in permeability. The range in permeability

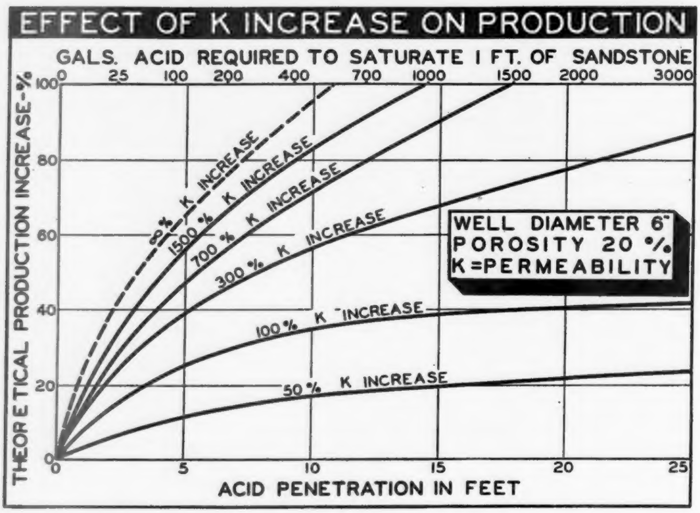

FIG. 6

increase shown in this figure is comparable with that obtained when cores are actually treated in the laboratory. The gallons of acid per foot of "pay" required to saturate a sandstone of 20 per cent porosity to a given radial distance is shown by the scale at the top of the figure.

For example, 250 gallons of acid will saturate one foot of formation a radial distance of 7.5 feet. If a 300 per cent increase in permeability results from the presence of this acid in the pores, at least 50 per cent increase in production can be expected. However, the occurrence of channeling[24] due to formation irregularities will sometimes lead to even much greater production increases than those indicated by the chart.

[24] Morris Muskat and R. D. Wyckoff, "The Theory of Acid Treatment of Oil Wells Producing from Limestone Reservoirs," *Physics*, Vol. 7 (March, 1936), p. 107.

It will be recalled that the treatment of wells in Wyoming resulted in much larger production than would have been anticipated from laboratory study of the cores. It is known that fractures exist in the Wyoming sands in question and that they are partly or completely filled with secondary minerals such as calcite and hence it is very likely that channeling or widening of these partially filled fractures occurs during the treatment of the well.

TABLE IX

SUMMARY OF OKLAHOMA CORE DATA

Formation	*Number of Cores*	*Range*	*Average*
Bartlesville			
Solubility, %	6	1.2– 3.2	1.9
Porosity, % (before)		14.9– 22.0	18.4
Porosity, % (after)		15.0– 22.7	19.2
Permeability, M'd. (before)		0.3– 330	70.0
Permeability, M'd. (after)		0.3– 330	81.0
Permeability increase, %		0 – 113	26.7
"Wilcox"			
Solubility, %	2	14.8– —	14.8
Porosity, % (before)	2	9.5– 15.6	12.6
Porosity, % (after)	6	8.4– 16.4	12.4
Permeability, M'd. (before)	2	8.5– 270	83.3
Permeability, M'd. (after)	6	8.5–1,190	479.2
Permeability increase, %	5	0 –2,840	995
Boggy			
Solubility, %	1	4.8– —	—
Porosity, % (before)	3	10.5– 14.6	12.9
Porosity, % (after)	7	14 – 15.2	14.8
Permeability, M'd. (before)	3	82 – 586	271
Permeability, M'd. (after)	7	76 – 675	335
Permeability increase, %	6	8 – 96	48
Senora			
Solubility, %	—	— – —	—
Porosity, % (before)	1	13.8– —	—
Porosity, % (after)	1	21.5– —	—
Permeability, M'd. (before)	4	8.2– 11.5	10
Permeability, M'd. (after)	4	58 – 78	67
Permeability, increase %	4	58 – 850	508

Muskat[25] has considered mathematically the effect of acidizing fractured formations, and has shown that such large increases in production can be expected. For example, if a fracture initially 1 millimeter wide and existent throughout the vertical distance of the "pay" is doubled in width by the acid treatment, a 700 per cent increase in production can be expected. Such increases in production are not uncommon in Wyoming where fracturing is known to exist in the oil-producing formations in certain fields.

[25] M. Muskat, *The Flow of Homogeneous Fluids Through Porous Media*. McGraw-Hill Book Company, Inc. (1937), p. 427.

The remainder of this paper consists of a summary of the core studies by states and formations. Lack of space prohibits the inclusion of all the core data. The writers believe that these summaries contain all the pertinent data but it is hoped that when this work is finally completed all the data will be made available in the *Bulletin*.

TABLE X

SUMMARY OF KENTUCKY CORE DATA

Formation	*Number of Cores*	*Range*	*Average*
Corniferous			
Solubility, %	21	12 – 40	27
Porosity, % (before)	22	9.5– 17.5	14.6
Porosity, % (after)	—	— – —	—
Permeability, M'd. (before)	22	0.4– 148	20.5
Permeability, M'd. (after)	22	2.1– 848	144
Permeability increase, %	22	70 –3,950	640
Bethel			
Solubility, %	—	— – —	—
Porosity, % (before)	2	5.3– 12.8	9.0
Porosity, % (after)	2	6.7– 17.5	12.1
Permeability, M'd. (before)	2	15 – 17	16
Permeability, M'd. (after)	2	49 – 153	101
Permeability increase, %	2	6 – 168	97
Jackson			
Solubility, %	—	— – —	—
Porosity, % (before)	3	4.9– 14.8	10.2
Porosity, % (after)	3	7.3– 16.5	13.5
Permeability, M'd. (before)	3	0.4– 14.6	8.6
Permeability, M'd. (after)	3	7.7– 37	18.1
Permeability increase, %	3		

TABLE XI

SUMMARY OF KANSAS CORE DATA

Formation	*Number of Cores*	*Range*	*Average*
Peru			
Solubility, %	9	0.4 – 10.8	2.8
Porosity, % (before)	9	9.5 – 14.3	13.2
Porosity, % (after)	9	12.3 – 20.5	15.3
Permeability, M'd. (before)	10	0.18– 13.8	2.7
Permeability, M'd. (after)	10	0.39– 12.5	5.3
Permeability increase, %	—	0 –1,290	29.5

TABLE XII

SUMMARY OF TEXAS CORE DATA

Formation	Number of Cores	Range	Average
Holt			
Solubility, %	6	0.8– 2.8	1.9
Porosity, % (before)	4	18.8– 22.8	20.8
Porosity, % (after)	10	21.1– 23.7	22.8
Permeability, M'd. (before)	4	116 –1,000	326
Permeability, M'd. (after)	10	150 –1,010	615
Permeability increase, %	10	0 – 525	108

TABLE XIII

SUMMARY OF PENNSYLVANIA CORE DATA

Formation	Number of Cores	Range	Average
Bradford			
Solubility, %	2	1.6 – 2.0	1.8
Porosity, % (before)	11	11.3 – 17.5	13.6
Porosity, % (after)	11	11.8 – 19.9	15.9
Permeability, M'd. (before)	11	0.74– 12.4	6.8
Permeability, M'd. (after)	11	1.5 – 77	21.8
Permeability increase, %	11	0 –670	17.6

TABLE XIV

SUMMARY OF LOUISIANA CORE DATA

Formation	Number of Cores	Range	Average
Glen Rose			
Solubility, %	6	15 – 31	22
Porosity, % (before)	—	Not determined	
Porosity, % (after)	—	Not determined	
Permeability, M'd. (before)	6	.8– 4.8	2.5
Permeability, M'd. (after)	6	28 – 650	202
Permeability increase, %	6	1,200 –211,150	8,120

TABLE XV

SUMMARY OF MICHIGAN CORE DATA

Formation	Number of Cores	Range	Average
Michigan Stray			
Solubility, %	—	—	—
Permeability, M'd. (before)	9	2.6–733	291
Permeability, M'd. (after)	9	4.3–755	375
Permeability increase, %	9	0 –193	40

TABLE XVI

SUMMARY OF CALIFORNIA CORE DATA

Formation	*Number of Cores*	*Range*	*Average*
Miocene			
Solubility, %	6	7.9– 23.6	10.7
Porosity, % (before)	6	10 – 22	16.1
Porosity, % (after)	32	0.8– 720	78
Permeability, M'd. (before)	6	12.2– 22.8	16.9
Permeability, M'd. (after)	32	1.0 660	88
Permeability increase, %	25	0 – 200	55
Kettleman Hills Zones 2, 3, 4, and 5			
Solubility, %	30	1.2– 3	1
Porosity, % (before)	30	9.4– 23.9	19.3
Porosity, % (after)	30	11.4– 28.6	19.7
Permeability, M'd. (before)	30	1.7–1,750	337
Permeability, M'd. (after)	30	1.3–2,600	4,448
Permeability increase, %	20	0 – 900	129
Capitan Field			
Solubility, %	5	0.4– 2	.7
Porosity, % (before)	5	17.4– 24.4	20.8
Porosity, % (after)	5	21.1– 33	26.2
Permeability, M'd. (before)	5	16 –1,450	632
Permeability, M'd. (after)	4	220 –1,600	938
Permeability increase, %	4	10.3– 33.3	22.6

TABLE XVII

SUMMARY OF ILLINOIS CORE DATA

Formation	*Number of Cores*	*Range*	*Average*
Weiler			
Solubility, %	14	N.M.*– 18.2	11.2
Permeability, M'd. (before)	14	10 – 775	348
Permeability, M'd. (after)	14	55 –1,200	596
Permeability increase, %	14	5 – 575	164
Bethel			
Solubility, %	—	3.0 – 14.0	9.6
Porosity, % (before)	23	7.45– 24.3	18.5
Porosity, % (after)	23	11.2 – 26.8	20.5
Permeability, M'd. (before)	29	3.6 – —	132
Permeability, M'd. (after)	29	7 –1,400	228
Permeability increase, %	25	0.0 – 543	80
Permeability decrease, %	4	0.0 – 8.7	—
Aux Vases			
Solubility, %	14	1.9 – 30	16.7
Permeability, M'd. (before)	14	0.3 – 6.6	2.7
Permeability, M'd. (after)	13	4.4 – 330	55.0
Permeability, increase, %	11	71 –5,300	1,240

* Not measurable.

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CROSS SECTION OF CHESTER OF ILLINOIS BASIN[1]

P. L. DANA AND E. H. SCOBEY[2]
Mattoon, Illinois

ABSTRACT

The correlations of the formations of the Chester from Randolph County, Illinois, to Hancock County, Kentucky, are illustrated with a series of sample logs. Basal Pennsylvanian sands and shales rest unconformably on various Chester formations from the Menard to the Kinkaid. The Menard, Glen Dean, Hardinsburg, Golconda, and Cypress formations are shown to be continuous across the basin. An eastward thickening into the basin of the strata lying above the distinctive basal Paint Creek limestone and beneath the Golconda formation and a compensating eastward thinning of the strata between the basal Paint Creek limestone and the Ste. Genevieve are noted. The sandstones, shales, and thin limestones between the Paint Creek and the Ste. Genevieve are traced eastward into the deep part of the basin where they appear to grade laterally eastward into heavy limestones which some workers have considered to be of Ste. Genevieve age.

INTRODUCTION

In the course of subsurface studies of the Chester series in the Illinois basin, certain critical lithologies have been observed, per-

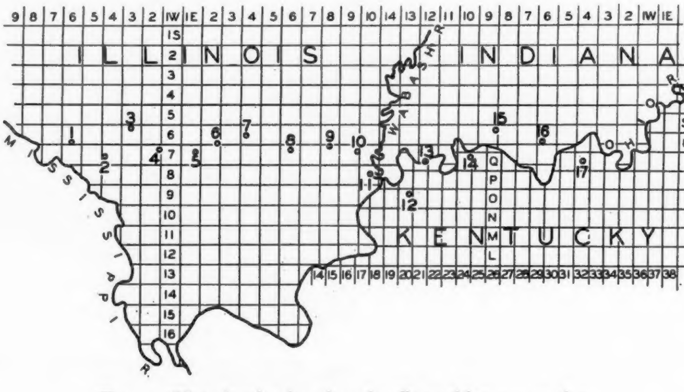

FIG. 1.—Map showing location of wells used in cross section.

mitting the correlation of formations over wide areas. From some 80 sample logs scattered over a zone 25 miles wide north and south, a group of 17 logs has been selected to construct an east-west cross

[1] Read before the Association at Chicago, April 11, 1940. Manuscript received, November 18, 1940.

[2] Gulf Refining Company, eastern production division. The writers are indebted to the Gulf Oil Corporation for permission to use logs from their files. A. L. Latta has collaborated in sample studies and correlations in Illinois. Assistance with the section in Indiana and Kentucky was received from C. W. Honess and C. L. Matthews of the Evansville office of the Gulf Oil Corporation. B. F. Hake and Carl B. Anderson encouraged and made valuable suggestions in the preparation of the paper.

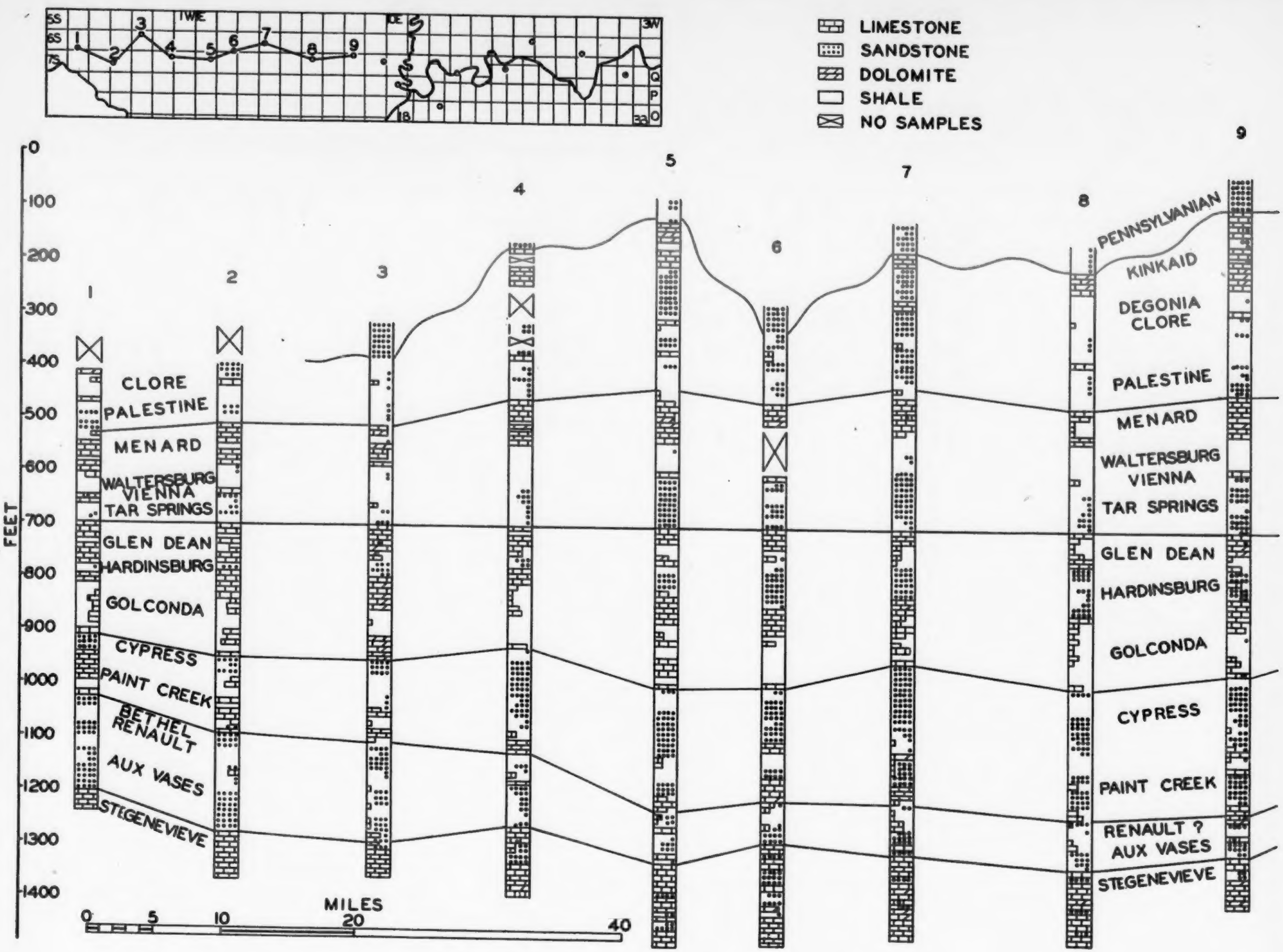

FIG. 2.—Western part of cross section of Illinois basin.

section of the basin (Figs. 1, 2, and 3). The maximum distance between the wells used is 15 miles, and the average distance is 11 miles. The cross section illustrates the conclusions and hypotheses resulting from the study of well samples and serves to indicate the basis for correlations of the various names applied by subsurface workers to Chester horizons in Illinois, Indiana, and Kentucky.

The western terminus of the section is in Randolph County, Illinois, a few miles from an area where some of the Chester formations are exposed. The cross section extends east to a point in Hancock County, Kentucky, approximately 15 miles west of an area of Chester outcrop. The section has not been extended into the outcrops at either end because of the writers' unfamiliarity with the surface beds. However, the Illinois State Geological Survey has studied the rocks of Randolph and Madison counties, and has correlated the wells in this area with them. The formation names shown here are in essential agreement with the State Survey determinations[3] and with the nomenclature applied by the subsurface workers in Illinois. To avoid confusion, the Illinois terminology is carried into Indiana and Kentucky.

CHESTER SERIES

The Chester series comprises cyclic deposits of sandstone, and shale and limestone. Clastic sediments predominate. The Chester is separated from the overlying Pennsylvanian by an angular unconformity. In some wells shown on the cross section, post-Chester erosion has removed all sediments down almost to the Menard limestone. The lowermost Chester rocks rest on the Ste. Genevieve limestone.[4]

The limestones and dolomites of the Chester are characterized by their variability, most commonly consisting of crystalline, clastic, and fossiliferous material. The limestones above the Glen Dean are in general more finely crystalline and darker in color than those below. Certain of these limestones have been found to serve best the purposes of long-distance correlation. They are separated by intervals of 200–300 feet and thus break up the Chester section into zones for comparison of characters and intervals. From top to bottom the important limestones are the Kinkaid, Menard, Glen Dean, basal Golconda, and basal Paint Creek. The correlation lines on the cross section are drawn at the tops or bottoms of these limestones.

[3] Mimeographed sample studies released by the Illinois State Geological Survey.

[4] In this paper the writers have not used the more recent classification of the horizons near the contact of the Chester and the Ste. Genevieve as proposed by J. Marvin Weller, "Mississippian System," *Guide Book 13th Ann. Field Conference Kansas Geol. Soc.* Because no good criteria have been found for determining the top of the Hoffner in samples the general practice of locating the base of the Chester on top of the Levias (lower O'Hara) limestone is still followed.

FIG. 2.—Western part of cross section of Illinois basin.

The dominant shale of the Chester is gray to very dark gray, platy, and brittle. Red and green or greenish gray shales are common and may be soft and crumbly or hard and brittle.

The Chester sandstones are very fine to medium in grain size, angular to subangular, and well cemented to friable. Coarse sand, if present, is generally confined to the base of the Tar Springs, Cypress, and Paint Creek sandstones. Well rounded sand grains are rare.

KINKAID, DEGONIA, CLORE, AND PALESTINE FORMATIONS

The highest correlation line on the section is drawn on top of the Menard limestone. The overlying Kinkaid, Degonia, Clore, and Palestine formations are not as well represented as the lower horizons because of the angular Pennsylvanian-Mississippian unconformity. The Kinkaid is the most distinctive formation of this group. In Illinois it consists of two heavy limestones separated by green shale and siltstone. Below the second limestone are some red and green shales. The upper limestone is fine-crystalline, in places cherty and varies from light gray to drab or dark gray in color. The lower limestone is fine-crystalline, in places crinoidal, and light to brownish gray in color. There is normally a drab, sublithographic bed at the base. Both limestones here and there contain dolomite or dolomitic beds. The maximum thickness of the Kinkaid represented in the section is 150 feet in well No. 9.

The Degonia, Clore, and Palestine formations are ordinarily difficult to separate. The Degonia is represented by sandstones and shales of variable thicknesses. The Clore is a limestone, shale, and sandstone formation. In Illinois there are everywhere one or two thin limestones present in this formation and these vary considerably in lithology, being normally finely crystalline in texture and gray, brownish or drab in color. Some dolomite beds are found at the Clore horizon in Indiana and Kentucky. The Palestine is predominantly a sandstone formation with varying amounts of shale. It is 50–150 feet thick in Illinois and appears to become thinner and more shaly on the eastern flank of the basin.

The interval from the top of the Chester to the top of the Menard limestone varies from a few feet to 350 feet in the wells shown on the section. Post-Chester erosion accounts for the extreme variation. In Indiana and Kentucky three of the wells show a limestone that has been called Kinkaid and it might be correlated with the lower Kinkaid limestone of Illinois. If so, there is considerable thinning toward the east flank of the basin.

MENARD, WALTERSBURG, VIENNA, AND TAR SPRINGS FORMATIONS

The Menard formation is essentially a limestone with some shale breaks. The top is drawn on the first limestone although some of the shale immediately above the limestone may belong in the Menard formation. The top of the limestone is more easily determined from samples and appears to be a good point for correlation purposes. The limestone is mainly very fine- to fine-crystalline in texture and gray to drab or dark brownish in color. Here and there mottled beds are found and a little chert is present in some wells. A dolomite zone has been noted at about the middle of the formation in most of the wells. In Indiana and Kentucky a dolomite is also found at the base and the basal bed in Illinois is in some places dolomitic. The Menard has a rather uniform thickness of 70–90 feet over most of the cross section.

In most of the wells the Waltersburg consists of greenish gray shale with minor amounts of siltstone and sandstone. Sandstone is most prominent in the deep part of the basin.

The Vienna limestone is thin but persistent. The maximum thickness noted on the cross section was 17 feet. Through the western half of the area it is fine- to coarse-crystalline and light brown to brown. It becomes sandy and cherty on the west end. At the east it is medium- to coarse-crystalline, crinoidal, and gray or brown to dark or mottled. It is known as the "Brown lime" to the drillers of Kentucky.

The Tar Springs occupies the interval between the Vienna and Glen Dean limestones. It is normally a sandstone but shale makes up the bulk of the formation in a few places. The sand is characterized by numerous tarry partings. The thickness of the Tar Springs varies from about 35 feet on the west flank of the basin to 130 feet in the deeper areas. The easternmost wells show a lenticular limestone in the Tar Springs. It is light-colored, coarse-crystalline, crinoidal, and sandy. It is referred to by some sample workers as the "false Glen Dean" or "upper Glen Dean." It is called the "second Brown lime" by drillers in this area and the sand below is termed the "Jett" or "second Jett."

The zone including the four formations described in the preceding paragraphs has been traced throughout the length of the cross section. It is approximately 170 feet thick in wells No. 1 and No. 17, and 295 feet thick in wells No. 12 and No. 13. The thinning of this zone on the flanks of the basin is accounted for in the thinner Waltersburg and Tar Springs formations.

GLEN DEAN, HARDINSBURG, AND GOLCONDA FORMATIONS

The Glen Dean limestone is persistent throughout the Illinois

basin. It is probably the best known limestone and the most widely used marker bed for correlating and contouring. The datum line of the cross section is drawn at the top of this limestone. Some of the shales included in the basal Tar Springs may be more closely related to the Glen Dean but the contact at the top of the limestone is much easier to pick in samples and forms a better point for correlation.

The Glen Dean is predominantly limestone but it contains varying amounts of shale and in a few places the shale constitutes nearly 50 per cent of the total thickness. Most of the calcareous beds are medium- to coarse-crystalline but some fine-crystalline limestone may be present. Beds containing fragmental material consisting largely of broken fossils and crinoid stems are common. Poorly developed oölites were found in about half of the wells and minor amounts of chert are present in the eastern half of the cross section. The Glen Dean is most commonly light brownish but varies through light to dark shades of gray and brown. Some of the beds have a mottled or splotched appearance. Although many types of lithology are represented in the Glen Dean only a few of them are similar to those found in the overlying formations. The limestone thins from west to east, that is, it is 75 feet thick in wells No. 1 to No. 3 and only 30 feet thick in wells No. 15 to No. 17.

The Hardinsburg is a sandstone, siltstone, and shale formation with sandstone predominating. In Illinois there is normally a zone of red and green shale and red dolomite or dolomitic shale at the base of the formation. This formation has a wide variation in thickness, ranging from 15 feet on the west end of the section to 150 feet in well No. 13.

The Golconda formation normally consists of a heavy upper limestone, a thick shale with some limestone or sand, and a thin basal limestone. The upper limestones exhibit a wide lithologic variety. The more common types are coarse- to fine-crystalline, detrital, crinoidal, fossiliferous, here and there with dolomitic beds, and in a few places rounded grains or pebbles of limestone. Oölitic beds are present in Illinois. Some chert occurs in this limestone in southeastern Illinois and it is prominent in Kentucky and Indiana. Shale is present in minor amounts. The middle Golconda consists primarily of shale but includes some limestones. Sand is almost entirely absent in Illinois, but sands, sandy shales and thin calcareous beds are ordinarily present in the Kentucky-Indiana part of the section. In this area they are called the Jackson or Cypress sandstone. This sand is separated from the beds correlative with the Cypress of Illinois by the basal Golconda limestone.

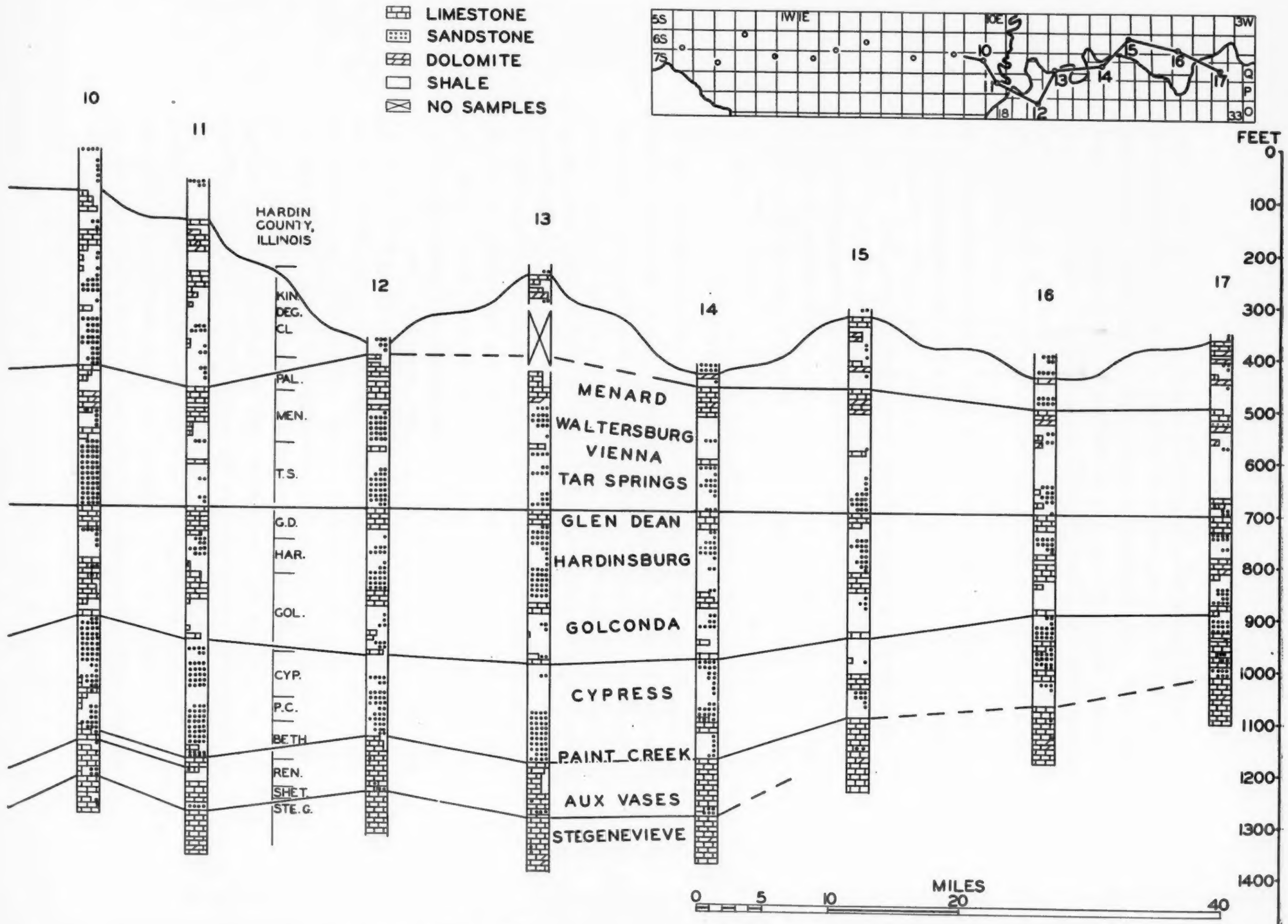

FIG. 3.—Eastern part of cross section of Illinois basin.

The basal Golconda limestone is a thin but very persistent limestone constituting one of the best marker beds in the basin. In the area of the cross section it is gray, fine-crystalline to granular, and contains black pellets or pseudo-oölites, giving it a mottled appearance. A fine-crystalline, gray to drab, or a detrital, crinoidal limestone may also be present in this basal member. Drillers and subsurface workers in Indiana and Kentucky know this limestone as the "Barlow lime."

The Golconda formation is more than 100 feet thick in all of the wells and reaches its maximum thickness of 185 feet in well No. 5. The basal limestone varies from approximately 5 to 15 feet in thickness.

The unit including the Glen Dean, Hardinsburg, and Golconda formations is readily traced across the Illinois basin. It is marked at the top and bottom by distinctive limestone beds. The total thickness of the unit is between 190 and 300 feet in the wells shown, being comparatively thin on both flanks of the basin and generally thick out in the deeper areas.

CYPRESS AND PAINT CREEK FORMATIONS

In this cross section the contact of the Golconda and the Cypress has been drawn at the base of the lowest Golconda limestone. Variable amounts of shale are ordinarily present between this limestone and the Cypress sandstone and some workers prefer to include part or all of this shale in the Golconda rather than the Cypress. Because of abrupt lateral changes from sand to shale in the upper part of the Cypress and the difficulty of picking contacts in a rather uniform shale section, the authors have found that more consistent correlations are possible by placing the top of the Cypress at the base of the overlying limestone. This procedure may vary somewhat from the original outcrop nomenclature.

Variations in the proportions of sand and shale in the Cypress are extreme. The shales are more prominent in the upper part of the formation and the sands in the lower part. The sand is often termed the Weiler in Illinois and the Barlow sandstone in Indiana and Kentucky. The contact of the Cypress with the underlying shale and sand of the Paint Creek is difficult to determine in the deeper Basin area, whereas a definite change is evident on the west flank where limestone and red and green shale predominate in the Paint Creek.

The upper limestones of the Paint Creek include many types of crystalline and detrital material, are in some places fossiliferous, oölitic, dolomitic, or cherty, and vary in color. These limestones and the associated shales are extremely variable laterally and vertically. The limestones thin out toward the east and are absent in wells Nos.

11, 12, and 13. They reappear in well No. 14. The upper limestone is called the Bethel limestone and the lower the Renault in wells in Indiana and Kentucky. They may be equivalent to the upper Paint Creek limestones and shales farther west or the thin upper limestone may be Cypress in age. Sand is prominent in the middle Paint Creek east of well No. 4.

The basal Paint Creek limestone has been proved to be a very valuable key bed in sample log correlation. It normally consists in part of coarse-crystalline, white, crinoidal limestone and may have a vitreous appearance. Fine-crystalline to granular and light to drab limestones are associated with this white limestone. Salmon or pink-colored chert replaces some of the calcite crystals and crinoid stems. These cherty pink crinoids are not found in all the wells but are found in a majority in Illinois, particularly on the west flank. Even where they are not present, the limestone itself can ordinarily be distinguished from other Chester limestones. This white limestone and red chert has been identified as far east as well No. 15. The top of the Ste. Genevieve has been determined on this horizon in many wells along the Ohio River.

A correlation line has been drawn on the base of this limestone across Illinois. In Kentucky and Indiana the base of the lime is difficult to determine because it lies directly on subjacent limestones without a sharp lithologic break. Therefore, the correlation has been continued to the east at the top of the basal Paint Creek limestone. The correlation is tentative in the last two wells.

The zone including the Cypress and the Paint Creek formations more than doubles in thickness from the west flank into the basin as the sands become thicker and replace part of the limestones and shales. The zone including the Cypress and the part of the Paint Creek above the basal limestone is considerably thinner on the east flank than in the basin and limestone and shale are again prominent in the section.

BETHEL, RENAULT, AND AUX VASES FORMATIONS

The Bethel or Benoist sandstone is found underlying the basal Paint Creek limestone in wells No. 1 to No. 4 but to the east no clean sands occur at this horizon. Its position is ordinarily occupied by a thin dolomite and a thin sandy limestone containing fine rounded calcareous pebbles. This type of sediment is common in the Renault and Aux Vases so the Benoist may be absent east of well No. 4.

The Renault and Aux Vases are difficult to separate and in the cross section no attempt has been made to do so. This interval is sand with a minor amount of shale on the west end of the section. Eastward,

thin limestones appear, but sand remains prominent as far as well No. 9. East of well No. 9, no heavy sandstones are encountered below the basal Paint Creek limestone but a sandy zone probably representing the basal part of the Aux Vases serves to continue the recognizable contact of the Chester and the Ste. Genevieve to well No. 14.

In the Renault and Aux Vases detrital limestones are common and red and green shales and thin dolomites are present. Some of the limestones are oölitic and many oölites are red, olive or yellow. There are beds in which the oölites consist largely of red iron oxide. In some places there are beds of coarsely crystalline, crinoidal limestone with white, pink, or light greenish calcite crystals or crinoids. This lithologic character might be mistaken for that of the basal Paint Creek except for the fact that the pink grains are composed of calcite, rather than chert.

The common subsurface terminology in Indiana and Kentucky places the top of the Ste. Genevieve at the top of the basal Paint Creek limestone as traced across Illinois. If this is correct the Renault-Aux Vases section of Illinois is pinched out in the vicinity of the Wabash River. Below the basal Paint Creek limestone in the Ohio River area there occur 75–90 feet of limestones with minor amounts of shale and a basal sandy zone. Many of these limestone beds exhibit lithologic features commonly found in the Renault and Aux Vases in Illinois, but not present in the Ste. Genevieve there. On the basis of the lithologic character of the beds in question and the thickness of the zone they comprise, it appears that the tendency to become more calcareous from the west flank into the basin is continued into Indiana and Kentucky and results in an almost continuous limestone sequence in the area of the eastern part of the cross section. The total thickness of the zone decreases from well No. 1 to well No. 5 and then maintains a uniform thickness east to well No. 14.

The most notable feature of this zone is the change from thick sands and shales on the west flank of the basin through a much thinner and more calcareous group of rocks to the predominantly limestone section of the Ohio River area. The change eastward into the basin is the reverse of that noted for the Cypress-Paint Creek formations.

CONCLUSION

A skeleton log has been inserted between wells No. 11 and No. 12 (Fig. 3). It was prepared from the average thicknesses of formations as given by Stuart Weller[5] for Hardin County, Illinois, approximately 25 miles south of the line of the cross section. Although too far away

[5] Stuart Weller, "The Geology of Hardin County," *Illinois Geol. Survey Bull. 41* (1920), Pl. 1.

for reliable correlations, it serves to compare the names on the cross section as carried from southwestern Illinois, with the outcrops of southern Illinois. Above the Paint Creek there is general agreement in

<table>
<tr><th colspan="2">CORRELATION OF SUBSURFACE NOMENCLATURE OF THE CHESTER</th></tr>
<tr><th>SOUTHWESTERN ILLINOIS</th><th>INDIANA AND KENTUCKY</th></tr>
<tr><td>KINKAID</td><td>KINKAID</td></tr>
<tr><td>DEGONIA CLORE
PALESTINE</td><td>DEGONIA CLORE
PALESTINE</td></tr>
<tr><td>MENARD</td><td>MENARD</td></tr>
<tr><td>WALTERSBURG</td><td>WALTERSBURG</td></tr>
<tr><td>VIENNA</td><td>VIENNA</td></tr>
<tr><td>TAR SPRINGS</td><td>TAR SRRINGS</td></tr>
<tr><td>GLEN DEAN</td><td>GLEN DEAN</td></tr>
<tr><td>HARDINSBURG</td><td>HARDINSBURG</td></tr>
<tr><td rowspan="3">GOLCONDA</td><td>GOLCONDA</td></tr>
<tr><td>CYPRESS OR JACKSON</td></tr>
<tr><td>BARLOW LIMESTONE</td></tr>
<tr><td rowspan="5">CYPRESS

PAINT CREEK</td><td>BARLOW SANDSTONE</td></tr>
<tr><td>BETHEL LIMESTONE</td></tr>
<tr><td>BETHEL SANDSTONE</td></tr>
<tr><td>RENAULT</td></tr>
<tr><td>AUX VASES</td></tr>
<tr><td>BETHEL</td><td rowspan="3">STE GENEVIEVE</td></tr>
<tr><td>RENAULT
AUX VASES</td></tr>
<tr><td>STE.GENEVIEVE</td></tr>
</table>

FIG. 4.—Table showing relations of formation names commonly used by subsurface workers in Illinois, Indiana, and Kentucky.

intervals and nomenclature although Weller did not include the Waltersburg and Vienna formations in his section. The Paint Creek shown on the Hardin County section consists of 40–50 feet of shale

with calcareous layers. It appears to be equivalent to the shale separating the two heavy sands in the Cypress-Paint Creek section in well No. 11. The Bethel of Hardin County is probably correlative with the Paint Creek sand of the cross section and is therefore absent on the west flank of the basin. The diagnostic basal Paint Creek limestone of the cross section may be correlative with the Renault of Hardin County. Additional sample studies to permit accurate correlations with the southern Illinois or the western Kentucky outcrops will be necessary to verify this tentative correlation. If it is correct the Bethel or Benoist of southwestern Illinois is older than the Bethel of Hardin County which has been correlated with the type section in western Kentucky.

A table (Fig. 4) has been prepared to summarize the writers' conclusions concerning the relations of the formation names commonly used by subsurface workers in Illinois, Indiana, and Kentucky. No discrepancies are noted above the Golconda. The Golconda of Illinois is shown as equivalent to the Golconda, Cypress, and Barlow limestone along the Ohio River.

Wells Used in Cross Section of Illinois Basin

	Section	*Township*	*Range*
1. Above Glen Dean—Gass' Schulze No. 1	2	7 S.	6 W.
Glen Dean and below—Houston's Gremmels No. 1	22	7 S.	6 W.
2. Stanolind's Leiner No. 1	20	7 S.	4 W.
3. Amerada's Pyramid No. 1	10	6 S.	3 W.
4. Eason's Bowlin No. 1	12	7 S.	2 W.
5. Amerada's Zeigler Coal Co. No. 1	14	7 S.	1 E.
6. Eason's Orient No. 1	36	6 S.	2 E.
7. Gulf's U. S. Fuel No. 1	20	6 S.	4 E.
8. Alma's Federal Chem. & Coke Co. No. 1	9	7 S.	6 E.
9. Pyramid's Wade No. 1	4	7 S.	8 E.
10. Wilson's Dagley No. 1	12	7 S.	9 E.
11. Kingwood's Egyptian Tie & Timber Co. No. 1	15	8 S.	10 E.
12. Hoagen's Greenwell No. 1	9	O	20
13. Locket & Gish's Diamond Island No. 1	10	Q	21
14. Kennard's Mann No. 1	10	Q	24
15. Gulf's Withers No. 1	12	6 S.	9 W.
16. Schumaker *et al.* Miller No. 1	29	6 S.	6 W.
17. Leon's Gabbert No. 1	13	Q	32

The Cypress and Paint Creek formations of Illinois include the Barlow sandstone, the Bethel limestone and sandstone, the Renault, Aux Vases, and the uppermost member of the Ste. Genevieve of the subsurface workers in the Ohio River area. The Bethel or Benoist of the west flank of the basin probably does not occur farther east. The Renault and Aux Vases of Illinois are probably represented in the upper 100 feet of the so-called Ste. Genevieve in the area of the cross section east of the Wabash River.

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GEOLOGY OF FREEZEOUT MOUNTAIN-BALD MOUNTAIN AREA, CARBON COUNTY, WYOMING[1]

MILAN D. MARAVICH[2]
Laramie, Wyoming

ABSTRACT

The Freezeout Mountain-Bald Mountain area constitutes the southeastern end of the Freezeout Hills between the Laramie Range on the east, the Medicine Bow Range on the south, and the Wind River Range on the northwest. The main structural features of this area are two northeastward-trending anticlines and the intervening syncline. The northwest flank of the southeastern anticline is cut by a southeastward-dipping thrust. It is believed that the folds and the thrust were formed under northwest-southeast compressive stresses.

INTRODUCTION

Location.—This report describes the geology of the southeastern part of the Freezeout Hills. The area is located 15 miles northwest of the town of Medicine Bow, Carbon County, Wyoming (Fig. 1). The mapped area includes approximately 43 square miles of the northeastern part of Carbon County in Ts. 24 and 25 N., Rs. 78, 79, and 80 W. The Shirley Mountains are 5 miles west of the northwestern part of the area, and the Little Medicine Bow River is 8 miles east of the eastern boundary. The southern boundary is 2 miles north of the Medicine Bow River, and the northern boundary is 8 miles south of Muddy Creek.

Purpose.—The geologic work was undertaken for the purpose of (1) obtaining an accurate geologic map, (2) describing and interpreting the structural geology, (3) measuring in detail the stratigraphic sections, and (4) investigating the possible mineral deposits and ground-water resources of the area.

Field work.—The mapping was done with a plane table and telescopic alidade on the scale of 1 inch = 1,000 feet. Section and quarter section corners were used for orientation and base-line points. Stratigraphic sections were measured normal to strike and downdip, with the aid of the Brunton compass and a steel tape. The field work was begun July 24, 1939, and was completed on September 1, 1939.

Acknowledgments.—The writer wishes to express his thanks to S. H. Knight, State geologist, who supervised the field work and made possible the completion of this report through the facilities of the Geo-

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[2] University of Wyoming. Present address: Standard Oil and Gas Company, Tulsa, Oklahoma.

logical Survey of Wyoming. R. H. Beckwith's assistance in drafting procedure is greatly appreciated. Acknowledgment is due Reid Bryson of Denison University, Ohio, for his valuable assistance in the field. The coöperation and hospitality of Denver Miller and John Ellis, and the other ranchers in the region are acknowledged.

Previous geological investigations.—No previous detailed geological investigations involving this area have appeared in print. W. C. Knight (8)[3] published a stratigraphic section of the Jurassic rocks of the area. W. N. Logan (10) published a paper which deals with the stratigraphy and invertebrate paleontology of the Freezeout Hills area. W. T. Lee (9) made a stratigraphic survey and described the rock sequences of the Difficulty area (Fig. 1). C. E. Dobbin, C. F. Bowen, and H. W. Hoots (5) mapped the area south of Freezeout Mountain. J. E. Ferren (6) made a reconnaissance survey of the Shirley Mountain area (Fig. 1). Sections 12, 13, and 24, T. 24 N., R. 80 W., mapped by Ferren, were remapped for greater detail. A. F. Peterson (13) made a reconnaissance survey of the Shirley Basin and Bates Hole region 6 miles northwest of the area. H. J. Giddings (7) made a reconnaissance survey of a portion of the Laramie Basin north of Como anticline 3 miles east of the T. B. Ranch. C. H. Crickmay (4) measured a Jurassic section at the east end of Freezeout Hills. Joseph Neely (12) measured a Sundance section south of the T. B. Ranch in T. 24 N., R. 78 W. O. P. Brown (3) made a detailed survey of the Difficulty-Little Shirley Basin area adjoining that described in this paper on the west (Fig. 1).

Accessibility.—A graded road passes within ½ mile east of the eastern margin of the area. This road begins at Medicine Bow and continues to Casper, Wyoming. An improved road extends from the Medicine Bow-Casper road to the T. B. Ranch. This is the only road within the area. Trails and almost impassable wagon roads are scattered throughout the region.

TOPOGRAPHY AND DRAINAGE

The topography of the area is controlled by two northwest-trending anticlines and an intervening syncline. In general, the anticlines form ridges which increase in height and width southwestward, and the syncline forms a valley which increases in depth and decreases in width southwestward. The core of West Freezeout anticline, in the northwestern part of the area, stands out as a ridge 50–500 feet high and 2,000 feet to 1 mile wide. The core of Freezeout Mountain anti-

[3] Numbers in parentheses refer to list of references at end of article. A number following a colon in parentheses gives the page in the reference cited.

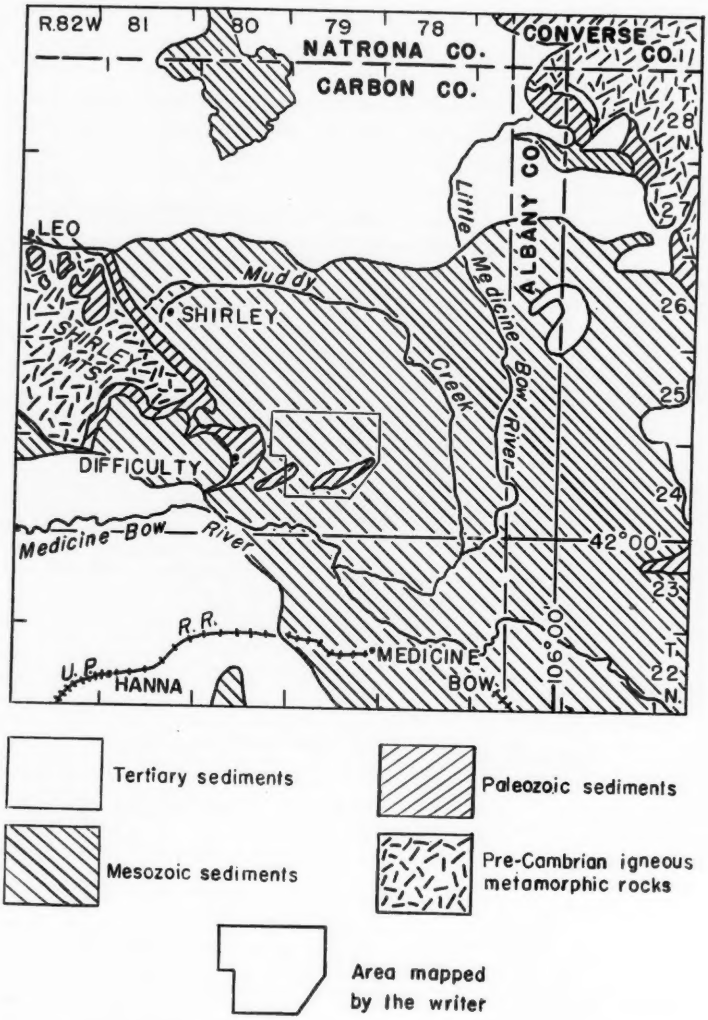


FIG. 1.—Index map of northeastern part of Carbon County, Wyoming.

cline, in the southeastern part of the area, stands out as a ridge 50–700 feet high and approximately 1 mile wide. A broad valley parallels this ridge on the south, east, and north and in turn is paralleled by a hogback which has an approximate height of 100 feet. This hogback is

paralleled by a higher hogback on the south and east and is separated from the first hogback by a narrow valley. The syncline, Freezeout Pasture, forming a valley in the central part of the area, ranges in depth from 0 to 800 feet and in width from 1,000 feet to more than 2 miles. In the north-central part of the area the syncline stands out as a mountain and has a height of approximately 500 feet.

TABLE I

STRATIGRAPHY OF FREEZEOUT MOUNTAIN-BALD MOUNTAIN AREA

Age	*Unit Mapped*	*Thickness in Feet*	*Description*
Upper Cretaceous	Frontier formation		Black shale with ferruginous concretions
	Mowry shale	117	Black to gray fine-bedded siliceous shale weathering to silver-gray with ferruginous discoloration
	Thermopolis shale	97	Black shale
Lower Cretaceous	Dakota group	260	Light brown medium-grained slabby quartzitic sandstone. Black and brown shales and sandy shales. Light brown to dark brown massive, fine-grained ferruginous quartzitic sandstone. White and brown thin-bedded gray shales. White to gray massive medium-grained sandstone with basal conglomerate that is quartzitic in places
Upper Jurassic	Morrison formation	216	Black shale. Light green shale with clay seam 3 feet thick. Maroon and green shale. Green, red, and maroon sandy shale
	Sundance formation	335	Gray to white thick-bedded sandstone. Purple fossiliferous limestone. Buff to gray sandstone with *Belemnites densus*. Red and gray shale and shaly sandstone. Greenish gray massive to thin-bedded cross-bedded sandstone
Triassic	Jelm formation	93	Red and green shales and sandstones with purple shale at top. Red sandstones and shales capped by greenish gray platy shaly sandstone. Greenish gray to pink fine-grained massive cross-bedded friable sandstone capped by slabby sandstone
	Alcova limestone	10	Crenulated ribbon limestone with small pelecypods
	Chugwater formation	689	Greenish gray fine-grained thin-bedded sandstone. Red sandy shale. Greenish gray sandstone. Alternating red and gray shales and sandy shales. Light orange shale. White gypsum with red and pink streaks
Permian	Embar group	338	Pale orange shale. Dirty gray dense dolomitic limestone. Maroon and red shale. Buff sandy shale. Dirty gray dense crenulated ribbon limestone with jasper concretions. Maroon polka-dot shaly sandstone. Gray gypsum on weathered surface; pure white on fresh fracture
Pennsylvanian	Tensleep sandstone	325	Brown to gray medium-grained cross-bedded sandstone
Pre-Pennsylvanian			Gray massive limestone

The Freezeout Mountain-Bald Mountain area lies in the drainage basin of the Medicine Bow River, a tributary of the North Platte River. There are no permanent streams in the area. However, the gulches draining the eastern part of the area empty into Muddy Creek, which in turn empties into the Little Medicine Bow River, the main tributary of the Medicine Bow River in this region. The western part of the area is drained by gulches emptying into Difficulty Creek, which flows into the Medicine Bow River.

STRATIGRAPHY

General statement.—The stratigraphic succession of the area (Table I) was assembled from exposures throughout Ts. 24 and 25 N. Thicknesses were measured with a Brunton compass and a steel tape with corrections for slope angles. Thicknesses were also computed from plane-table sheets by the formula:

$$T = WO \times \sin \phi$$

T being the thickness, WO being width of outcrop, and ϕ being the dip. The thickness of the succession compares favorably with that measured in the Difficulty-Little Shirley Basin area by Brown (3: 6).

Special notes on nomenclature.—The name "Embar group" is herein applied to the entire sequence between the Tensleep sandstone and the Chugwater formation. This is in agreement with the nomenclature of Brown (3: 7).

The term "Jelm formation" is here applied to the entire sequence between the Alcova limestone and the Sundance formation. This is a deviation from the nomenclature of Neely (12: 743). These distinctions were made in order to provide readily mappable units.

STRATIGRAPHIC SECTION OF MOWRY SHALE, THERMOPOLIS SHALE, AND DAKOTA GROUP, MEASURED SOUTHEAST OF FREEZEOUT MOUNTAIN IN SECS. 18 AND 19, T. 24 N., R. 78 W.

	Feet	Inches
Frontier formation		
Black shale with ferruginous concretions		
Mowry shale		
Black to gray fine-bedded siliceous shale weathering to silver-gray with ferruginous discoloration	117	
Thermopolis shale		
Black shale	96	6
Dakota group		
Light brown medium-grained slabby quartzitic sandstone	107	1
Brown fine-bedded sandy shale with worm tracks and gypsum. Black shales at base	32	4
Light brown to dark brown massive fine-grained ferruginous quartzitic sandstone	21	2

	Feet	Inches
White to brown fine-grained thin-bedded shaly sandstone with thin-bedded gray shales	19	7
White to brown sandy shale and brown quartzitic sandstone	28	8
White to brown sandy shale. Brown medium-grained quartzitic sandstone	15	3
Brown medium-grained quartzitic sandstone	14	5
White to gray massive medium-grained sandstone weathering to brown. Quartzitic in places with basal conglomerate	21	7
	260	1

Morrison formation

STRATIGRAPHIC SECTION OF MORRISON FORMATION, SUNDANCE FORMATION, JELM FORMATION, AND ALCOVA LIMESTONE, MEASURED NORTHWEST OF FREEZEOUT MOUNTAIN IN SEC. 32, T. 25 N., R. 78 W.

	Feet	Inches
Dakota group		
Morrison formation		
Black shale	39	
Black shale. Brown sandstone with siliceous stringers and clay seam 3 feet thick. Light green shale	43	10
Dark green to light green shale	43	10
Dark green shale. Maroon and green shale	48	6
Green, red and maroon shales. Red sandy shale. Green sandy shale	40	8
	215	10
Sundance formation		
Brown massive ferruginous sandstone. Green and red shales. Gray thick-bedded sandstone	49	11
Gray and brown sandstone	53	9
Gray and brown thin-bedded cross-laminated sandstone	15	3
Buff to gray sandstone with numerous *Belemnites*. Purple dense fossiliferous limestone 1 foot thick. Green fissile shales. Brown thin-bedded cross-laminated ferruginous sandstone. Coquina formed of pelecypods present in brown sandstone	37	9
Gray to green sandstone with *Belemnites* very abundant	24	3
Gray to buff medium to thin irregularly bedded cross-laminated sandstone. Worm trails and calcite stringers very common	6	11
Green to gray massive cross-bedded sandstone. Green to red fissile shales. Red and green sandy shales	40	6
Covered interval	43	10
Covered interval. *Belemnites* very common	32	7
Covered interval	18	3
Greenish gray massive to thin-bedded cross-laminated medium-grained sandstone	12	3
	335	4
Jelm formation		
Red and green shales and sandstones with purple shales at top. Red sandstones and shales capped by greenish gray platy shaly sandstone. Greenish gray to pink fine-grained massive cross-bedded friable sandstone capped by slabby red sandstone	48	6
Covered interval	22	11
Red shale	21	
	92	5
Alcova limestone		
Crenulated ribbon limestone with small pelecypods. Stands out as cliff	10	
Chugwater formation		

STRATIGRAPHIC SECTION OF CHUGWATER FORMATION, EMBAR GROUP, AND TENSLEEP SANDSTONE, MEASURED SOUTH OF FREEZEOUT MOUNTAIN IN SECS. 11 AND 14, T. 24 N., R. 79 W.

	Feet	*Inches*
Chugwater formation		
Greenish gray fine-grained thin-bedded sandstone. Greenish gray sandy shale	25	
Red and white fine-grained thin-bedded sandstone. Red sandstone. Red sandy shale	71	11
Red and white fine-grained thin-bedded sandstone. Red sandy shale. Red sandy shale and greenish gray fine-grained thin-bedded sandstone	58	10
Red and white fine-grained platy sandstone. Red sandstone. Red sandy shale. Greenish gray fine-grained thin-bedded sandstone. Red sandy shale	58	10
Red sandy shale. Greenish gray thin-bedded sandstone	42	4
Light orange sandy shale	42	4
Covered interval	270	11
Light orange sandy shale	20	10
Covered interval	42	5
Orange shale. White gypsum with red and pinkish streaks	17	5
Light orange shales. Greenish gray porous sandy marly limestone	12	3
Dirty gray gypsum; very soft and has hollow sound when walked on. Red shales. White gypsum with green and pinkish streaks	25	11
	689	
Embar group		
Pale orange shale. Dirty gray dense dolomitic limestone	45	
Pale orange shale	63	4
Dirty gray dense crenulated ribbon limestone with jasper concretions	15	9
Orange-red shale	10	
Maroon shale. Maroon color seems to be on weathered surface. On fresh fracture has orange-red color	22	6
Maroon polka-dot sandy shale. Dots are greenish gray. Weathers very commonly to small pebbles	35	1
Red and purple shale	14	10
Red and purple shale. Red to purple fine-grained platy shaly sandstone with numerous white specks	19	6
Red shale covered with white sandy shale pebbles	29	3
Red shale	19	
Reddish and greenish gypsum	5	3
Gray to reddish gypsum. Red clay and reddish and green gypsum. Has ferruginous appearance on weathered surface and dirty white on fresh fracture	7	11
Gray gypsum on weathered surface. Almost pure white on fresh fracture. Has very hollow sound when walked over	49	11
	337	4
Tensleep sandstone		
Brown to gray medium-grained cross-bedded sandstone with numerous calcite stringers	325	
Pre-Pennsylvanian		
Gray massive limestone		

STRUCTURE

General structural relations.—East of the area mapped by the writer, and north of Como anticline, the axial planes of the folds dip south (7: 37). Northwest of the mapped area the Shirley anticline and

Austin dome have axial planes dipping northeast and north, respectively (14: 42–44). In the area south of the Shirley Mountains (Fig. 1) the axial planes dip southeast (6: 25). In the Difficulty area (Fig. 1) the axial planes of the folds dip south or southeast with the exception of the Beer Mug anticline, which dips west (3: 17). South of the Freezeout Hills, in T. 23 N., R. 79 W., the axial plane of the Flat Top anticline dips south (5: 30). These relations show the direction of dip of the axial planes of the folds surrounding the area under discussion.

Structure of area mapped.—In order to facilitate a more detailed discussion of the structure, the area has been divided into three parts, corresponding with the topographic subdivisions used on page 884.

FREEZEOUT MOUNTAIN AREA

The Freezeout Mountain anticline extends across the entire southeastern part of the area. It is an asymmetric fold with steep dips on the northwest flank and more gentle dips on the southeast flank. It consists of a Tensleep core paralleled on the southeast flank by an Alcova-capped hogback, which in turn is paralleled by a higher Dakota-capped hogback. The axial plane of the fold dips 80°–85° SE. The axis plunges northeast and north. The trend of the fold from Sec. 19 to Sec. 1, T. 24 N., R. 79 W., is northeast. North of Sec. 1, the trend changes from northeast to north. This anticline dies out a few miles north of the area.

The Tensleep sandstone is exposed in the core of the anticline and the outcrop varies in width from a few hundred feet in Sec. 19, T. 24 N., R. 79 W., to more than 5,000 feet in the SW. ¼ of Sec. 2, and the NW. ¼ of Sec. 12, T. 24 N., R. 79 W. The dip of the Embar bed, in contact with the Tensleep core on the southeast flank, varies from 24° in Sec. 21, to 2° in Sec. 1, T. 24 N., R. 79 W. On the northwest flank the Embar has a dip of 2° in Sec. 1, and 45° in Sec. 10, T. 24 N., R. 79 W. The Embar group is separated from the Alcova-capped hogback by a broad valley. This valley is cut into the soft Chugwater shales and varies in width from approximately 1,000 feet in Sec. 19, T. 24 N., R. 79 W., to more than 2 miles in Secs. 31 and 36, T. 25 N., R. 79 W. The valley is paralleled on the southeast and east by the Alcova-capped hogback. The dip of the Alcova limestone decreases from 22° in the SW. ¼ of Sec. 19, T. 24 N., R. 79 W., to 9° in Sec. 32, T. 25 N., R. 78 W. A much narrower valley occurs between the Alcova and Dakota hogbacks. In general it parallels the larger valley, but merges into a broad plain immediately north of the area. These structural relations are shown in structure section *AA′* (Fig. 2).

The northwest flank of the Freezeout Mountain anticline is cut by

the Freezeout Mountain fault, which strikes approximately N. 65° E., and is a southeast-dipping thrust (Fig. 2). This fault is covered by alluvium in Sec. 24, T. 24 N., R. 80 W., and in Sec. 11, T. 24 N., R. 79 W. In Secs. 19, 18, 17, 16, 9 and 10, T. 24 N., R. 79 W., the fault was traced with little difficulty. Thus the fault has a minimum length of 5½ miles. Pennsylvanian and pre-Pennsylvanian sediments are exposed southeast of the fault contact, and Permian and Triassic sediments are exposed northwest of the fault contact. In Secs. 18, 19, the western parts of Secs. 10 and 17, and the extreme southeastern part of Sec. 9, the Tensleep sandstone is in contact with the basal gypsum of the Chugwater formation. In Secs. 10 and 11, the Tensleep sandstone is in contact with the upper Embar group. In Secs. 9, 16, and 17, pre-Pennsylvanian limestone is in contact with the basal gypsum of the Chugwater formation. This is the only locality in the area in which the pre-Pennsylvanian limestone is exposed. The maximum stratigraphic displacement is not more than 700 feet. This is in Secs. 9, 16 and 17, where the pre-Pennsylvanian limestone is in contact with the basal gypsum of the Chugwater formation. The relations of the Freezeout Mountain fault to the associated anticline are shown in structure section *BB'* (Fig. 2).

About 2 miles south of the southwestern corner of the area there is a marked left offset in the Dakota and Alcova hogbacks. This area was not investigated in detail, but it is the writer's belief that the Freezeout Mountain fault continues southward passing into a fault intermediate between a reverse fault and a tear. The tendency for a thrust fault to pass laterally into a fault intermediate between a reverse fault and a tear is not uncommon in Wyoming. Such structure has been mapped and explained, in the southwest margin of the Laramie Basin, Wyoming, by R. H. Beckwith (1: 1526–1542).

WEST FREEZEOUT ANTICLINE AREA

The West Freezeout anticline is located in the northwestern part of the area (Fig. 2). Like the Freezeout Mountain anticline it is asymmetric with steeper dips on the northwest flank than on the southeast flank. The axis of the fold trends approximately northeast from the NE. ¼ of Sec. 13, T. 24 N., R. 80 W., to the central part of the S. ½ of Sec. 5, T. 24 N., R. 79 W. From here to the NW. ¼, NW. ¼ of Sec. 33, T. 25 N., R. 79 W., the axis trends north. From Sec. 33, to the northern part of the area the axial trend is again northeast. The dip of the axial plane, where the trend is northeast, is approximately 85° SE., and 75° E. where the axial plane trends north.

The Tensleep sandstone forms the core of the anticline and is ex-

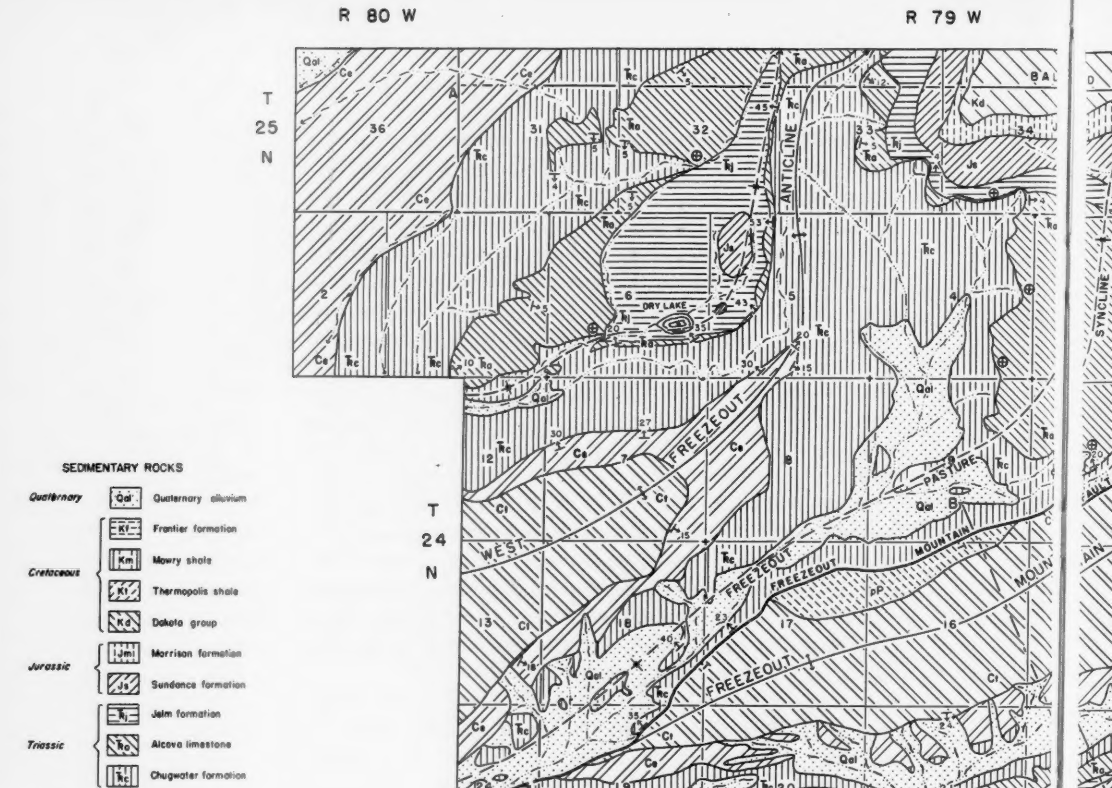
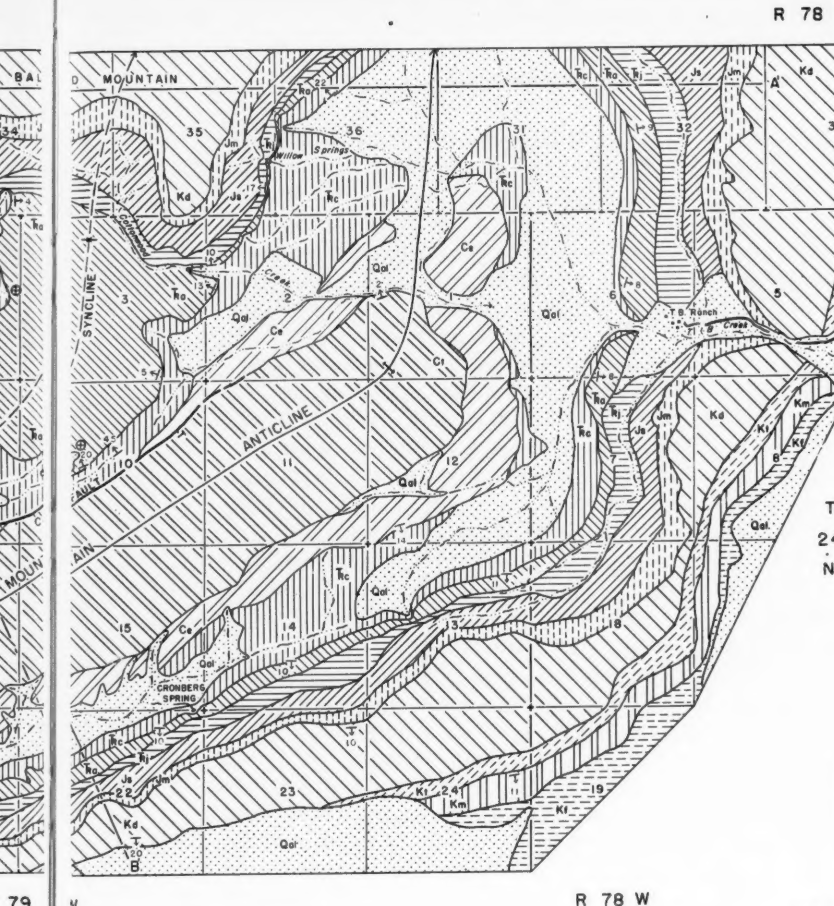
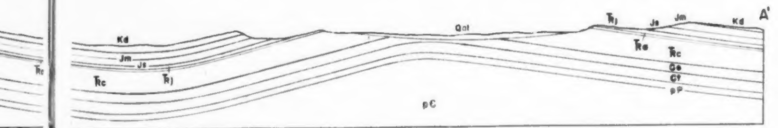
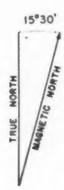


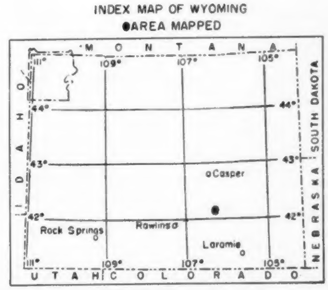
FIG. 2.—Geologic map and structure sections of Freezeout Mountain-Bald Mountain Area, Carbon County, Wyoming.

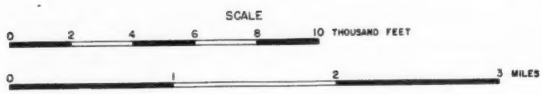
Geolo











ming.

Geological Survey of Wyoming, S. H. Knight, State geologist. Geology by M. Maravich. Plane table by R. Bryson. 1940.

posed in Secs. 12 and 13, T. 24 N., R. 80 W., and in Secs. 7 and 18, in T. 24 N., R. 79 W. On the southeast limb, the dip of the Embar is 18° in Sec. 13. The dip of the Embar, on the northwest limb, in Sec. 7, is 30°. In the central part of the S. ½ of Sec. 5, the Embar, forming the nose of the anticline, dips 15° on the southeast flank, 30° on the northwest flank, and 20° northeast at the nose.

On the east limb of the West Freezeout anticline, in Sec. 33, the Alcova limestone forms a north-trending hogback in which the beds dip between 5° and 12° E. The Alcova is also a hogback on the northwest limb of the anticline. In the SW. ¼ of Sec. 1, NE. ¼ of Sec. 12, T. 24 N., R. 80 W., the S. ½ of Sec. 6, SW. ¼ of Sec. 5, T. 24 N., R. 79 W., the Alcova strikes northeast and dips northwest between 20° and 43°. There is a marked change in strike from northeast to approximately due north from the central part of the W. ½ of Sec. 5, to the SE. ¼, NE. ¼ of Sec. 32, T. 25 N., R. 79 W. From the SE. ¼, NE. ¼ of Sec. 32, to the northern part of the area the strike changes again to northeast. Northward from the NW. ¼ of Sec. 5, the dip of the Alcova varies from 50° to 30°. The relations of this anticline to the Freezeout Mountain anticline are shown in structure section *AA′* (Fig. 2).

The Alcova forming the northwest flank of the West Freezeout anticline is the southeast flank of a small doubly plunging syncline. This syncline is completely closed by the Alcova limestone. The trend of this fold is approximately parallel with the strike of the Alcova limestone on the northwest flank of the West Freezeout anticline. The axial plane dips southeast and east. The fold plunges southwest from the NE. ¼, NE. ¼ of Sec. 32, T. 25 N., R. 79 W., and northeast from the NE. ¼ of Sec. 12, T. 24 N., R. 80 W. The fold axis is approximately horizontal in the W. ½ of Sec. 5. The dip of the Alcova on the northwest limb varies from 10° to 5°, toward the north. In the W. ½ of Sec. 5, there are two Sundance buttes in the trough of the syncline. The larger of these is approximately 1,000 feet wide, 2,000 feet long, and 50 feet high. Both consist mainly of horizontal beds of basal Sundance sandstone.

The lowest part of the syncline is in the SE. ¼ of Sec. 6, T. 24 N., R. 79 W., and is known as Dry Lake. Water is present in this lake only during thaws and for short periods after heavy rains.

FREEZEOUT PASTURE AREA

The Freezeout Pasture area is the intervening syncline between Freezeout Mountain and West Freezeout anticlines (Fig. 2). The dip of the axial plane and the plunge of the axis of this fold closely parallels

that of the Freezeout Mountain anticline (page 890). This syncline varies in width from approximately 1,000 feet in the NW. ¼ of Sec. 17, T. 24 N., R. 79 W., to more than 2½ miles in Secs. 33, 34, 35 and 36, T. 25 N., R. 79 W. The central part of the trough, from the SW. ¼ of Sec. 4, to the southwestern part of the area, is covered by alluvium. Scattered throughout the alluvium-filled trough are numerous small outcrops of Chugwater. These small remnants ordinarily consist of the upper sandy part of the formation. The flanks of the syncline, southwest of the SW. ¼ of Sec. 4, are made up of the lower Chugwater shales, and the entire syncline immediately north, east, and west of the SW. ¼ of Sec. 4, is cut in these shales.

A large mesa, capped by Alcova limestone, occurs in Sec. 3, the E. ½ of Sec. 4, and the NW. ¼ of Sec. 10, T. 24 N. The Alcova is horizontal on the western edge of this mesa. The dips on the eastern edge vary from 13° in the northern part to 20° in the southern part (Fig. 2).

Immediately north and northwest of the Alcova-capped mesa, in Secs. 33, 34, 35, and 36, T. 25 N., the Freezeout Pasture syncline is topographically expressed as a synclinal mountain and is known as "Bald Mountain" (Fig. 2). The Alcova limestone occurs at the base of the mountain and rests on the Chugwater formation. The top of the mountain is made up of the lower part of the Dakota group. The beds on the east flank of the mountain dip west and northwest between 17° and 22°. The dips on the western flank vary from 5° E. to 12° SE., and the dips of the beds on the south face of the mountain are between 4° and 10° N. Immediately north of the area this syncline flattens and merges into a broad plain. The relation of this syncline to the flanking anticlines is shown in structure section *AA′* (Fig. 2).

ECONOMIC RESOURCES

There are no economic resources of commercial value in this area. The gypsum in the Embar group and Chugwater formation is of good quality and extensive, but the remoteness of the exposures from graded roads and railroads prohibits the commercial production of this mineral.

The possibility of finding oil or gas in the folds exposed in the area is slight. The only formation which is not extensively exposed either in the cores or on the flanks of the anticlines and which might be a producer is the pre-Pennsylvanian limestone. The nature of this limestone is such that it is highly improbable that any oil is present. No exploration for oil and gas has been carried on in this area.

UNDERGROUND WATER

Due to the fact that the water needs of the ranchers have been generally served by springs, no wells have been dug or drilled in this area. Hence, the lack of data on which to base a detailed underground-water discussion.

There are numerous springs throughout the area, but most of these were not flowing during the writer's stay in the vicinity.

The source bed for the few flowing springs is either the upper sandy Chugwater beds or the basal Dakota sandstone. The two most important springs are in the SE. $\frac{1}{4}$, NE. $\frac{1}{4}$ of Sec. 3, T. 24 N., and the NE. $\frac{1}{4}$, SE. $\frac{1}{4}$ of Sec. 35, T. 25 N., R. 79 W. The first spring is in the upper sandy Chugwater beds and furnishes water for Cottonwood Creek. The latter spring is in the basal Dakota sandstone and furnishes water for Willow Springs. Both creeks dry up within a mile or two of their source.

There are two additional flowing springs in the area and both are in the upper sandy Chugwater beds. The domestic water supply for the T. B. Ranch comes from a small spring in the NW. $\frac{1}{4}$, SE. $\frac{1}{4}$ of Sec. 6, T. 24 N., R. 78 W., while water for livestock comes from the Cronberg Spring, in the NE. $\frac{1}{4}$, NE. $\frac{1}{4}$ of Sec. 22, T. 24 N., R. 79 W.

The Tensleep sandstone is exposed in the cores of the Freezeout Mountain and West Freezeout anticlines. Steep-walled gorges have been cut in these Tensleep cores, but no springs or seeps were observed. The extent to which the Tensleep may yield water in the synclinal troughs can only be determined by drilling.

CONCLUSIONS

Available evidence indicates that the mountain-making folding of the Laramie Basin area began in late Cretaceous time and continued intermittently to early Eocene time. There are no data within the area covered in this report whereby it is possible to date the disturbance which produced the Freezeout Mountain anticline, other than that it is post-Frontier in age. The forces applied to the area took the form of intense northwest-southeast compressive stresses.

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GEOLOGICAL NOTES

HAWKINS FIELD, WOOD COUNTY, TEXAS[1]

H. J. McLELLAN[2]
Tyler, Texas

The Hawkins oil field is located in southeastern Wood County in the north-central part of the East Texas basin. It is of particular interest to note that the discovery of this field must be attributed principally to surface geology and core drilling.

The presence of a small surface structure in this area was first reported by E. A. Wendlandt[3] in 1930. Core drilling in 1937 proved the structure to be much larger and more pronounced on the subsurface formations.

The discovery well, Bobby Manziel's Morrison No. 1, located $3\frac{1}{2}$ miles northwest of the town of Hawkins, was completed, December 20, 1940, at a depth of 4,963 feet, in the Woodbine, plugged back to 4,917 feet, with an initial production of 124 barrels of oil and about 290 barrels of salt water per day on the pump. The oil was black in color, with a gravity ranging from 15° to 18°. On December 29, the second producing well, Jackson and Rotundi's Cobb Heirs No. 1, located in the Hawkins townsite, was completed at a depth of 4,648 feet with an initial production of 122 barrels per hour through a one-inch tubing choke. The oil from this well was brownish black in color, with a gravity of 28.5°.

From present information it appears that the structure of the field is an elliptical dome with its major axis bearing about N. 7° E. The amount of structural relief increases with depth, being about 45 feet on the Weches, 200 feet on the Navarro, 350 feet on the Pecan Gap, and 900 feet on the Woodbine. Evidently numerous small faults are present.

At the surface are the Sparta and Weches formations of the Claiborne group. The subsurface formations encountered on top of the dome have the following average thicknesses.

	Feet
Claiborne	680
Wilcox	850
Midway	750
Navarro	500
Taylor	1,475
Austin	100
Eagle Ford	150
Woodbine	400

[1] Manuscript received, March 14, 1941.

[2] Geologist, Humble Oil and Refining Company.

[3] Geologist, Humble Oil and Refining Company.

Sands in the Claiborne and Wilcox contain fresh water, and sands in the Nacatoch member of the Navarro contain salt water.

The sub-Clarkville sand, which is present at the top of the Eagle Ford and is about 10 feet thick, contains gas on the top of the structure but has not been tested on the flanks.

Approximately the upper 180 feet of the Woodbine formation is composed of shale and redbeds with lenticular beds of shaly and ashy sand. The remainder of the section is made up of thick bodies of sand and thin irregular beds of shale, the average percentage of sand being about 75 per cent. From limited information, the estimated subsea depths to the gas-oil contact and water level are, respectively, 4,074 feet and 4,490 feet. The estimated subsea depths to the top and base of the Woodbine on the crest of the structure are 3,800 feet and 4,048 feet, respectively. Thus, over a limited area on the highest part of the structure, no Woodbine is present below the gas-oil contact.

Wells drilled to date indicate that the gravity of the oil decreases with depth, being about 29° near the gas-oil contact and 15° at the water level.

The field has a 20-acre spacing order with allowable based 50 per cent on acreage and 50 per cent on the well.

Except for the Hawkins townsite, most of the leases on this structure are controlled by the Humble Oil and Refining Company.

APPLIED SEDIMENTOLOGY[1]

HENRY CARTER REA[2]
Jackson, Mississippi

In the spring of 1937 the writer had the opportunity of reviewing a comprehensive report on the shoestring sand areas of Kansas and Oklahoma. The purpose of this study was to extend existing productive areas and develop new sand bodies with the least possible cost. The lenticularity and sporadic occurrence of the sand bodies accompanied by the absence of any surface reflection of subsurface conditions precluded the use of ordinary exploration methods. The shallow productive depths (2,000–2,500 feet) combined with long life and low operating costs were sufficient to stimulate the imagination.[3]

In discussing the problem with R. E. Shutt[4] at the time, the writer

[1] Manuscript received, March 17, 1941.

[2] Consulting geologist.

[3] For a detailed report and description of these sand bodies see N. Wood Bass, "The Origin of the Shoestring Sands of Greenwood and Butler Counties, Kansas," *Univ. Kansas Bull.* 23 (1936).

[4] Shell Oil Company, Tulsa, Oklahoma.

offered a method of approach which is applicable to many sedimentary problems in general and to the shoestring-sand areas in particular.

The suggested idea is based on the principle that normal sedimentary units do not terminate abruptly but "wedge" or thin out laterally. If this principle is accepted, the problem resolves itself into a detailed study of the sediments involved.

If the cuttings from a number of previously drilled wells in several adjacent sand bodies are studied microscopically and particular attention is paid to the characteristics of the material immediately overlying the sand body for a vertical distance of about 50 feet and laterally beyond the limits of the actual sand occurrence, the data so obtained can be used for control and location of other wells within the immediate area.

Again, if the cuttings from the sand bodies are examined in a similar manner, it will be noted that as the sand lens thins toward the edges there is a proportionate loss of certain constituents until the limit of the body is approached. At this point there are (a) very few sand grains, (b) no sand grains, (c) a different type of grain, or (d) a transitional phase of the sand into the inclosing siltstone mass. By recording these data on a map it is evident that the percentage amount or kind of certain types can be interpolated between any two wells within the given sand body. From the same information, the edge of the sand body can be located by extrapolation.

Studies of the well cuttings should not stop with the ordinary microscopic examination. The material should be examined under various conditions such as ultra-violet light, infra-red rays, and if possible be photographed by X-rays in an attempt to ascertain diagnostic diffraction patterns of any of the constituent grains. The use of these methods will enhance the possibilities of determining both individual and group characteristics of the sediment. The cuttings should also be subjected to the action of the common laboratory reagents in an endeavor to determine whether certain characteristics can be chemically induced. Geochemical analysis for the gas content in the overlying siltstone could be used as an accessory index. It is apparent that in the initial stages of this problem experimentation will account for some lost motion until a program of laboratory technique is formulated. The results of such a comprehensive investigation will immediately suggest methods of control in actual exploration with the drill which are not at first apparent.

The practical application of this information would necessitate the drilling of at least three wells in the area studied. The first two wells would necessarily be exploratory or "information" wells. The cuttings

from these two wells would be studied in the light of the previous experimental work and the information gained therefrom would be used to locate the third well. In the drilling of the exploratory wells the formations passed through would be considered in a very different light than so much sandstone and shale and the thin stringers of sand, heretofore passed by as a "stray," would be highly significant.

It is apparent that costs must be considered in any venture and a study of this kind is no exception. But, when it is remembered that the shoestring-sand areas do not lend themselves to the usual methods of exploration, a study of this nature is more economical than several wells drilled on the "hope-we-hit" basis.

The immediate criticism of the procedure outlined is the time element involved in the preparatory investigation. This objection can be offset by the fact that the search for reserves in the United States will entail greater expenditures for geological research work as present reserves decline.

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REVIEWS AND NEW PUBLICATIONS

* Subjects indicated by asterisk are in the Association library, and available, for loan, to members and associates.

STRENGTH AND STRUCTURE OF THE EARTH, BY R. A. DALY

REVIEW BY WILLIAM W. RUBEY[1]
Washington, D. C.

Strength and Structure of the Earth, by R. A. Daly. ix+434 pp., 85 figs., 69 tables. Prentice-Hall, Inc., New York (1940). Price, $3.50.

This book might have been entitled "Isotasy, Review and Probable Interpretation," for it has these two clearly stated aims: (1) to summarize in a single convenient volume the scattered literature of isostasy and (2) to appraise what plumb-line and gravity observations actually demonstrate about the strength and gross structure of the earth at shallow and intermediate depths.

In the first of these two objectives, Professor Daly has been eminently successful. By far the greater part of the volume is a compilation of the observational data and essential ideas on which the theory of isostasy has been built. After a preliminary discussion of the technical terms that have caused most confusion, the author proceeds to retrace major steps in the development of the idea of isostatic equilibrium. Much of this history is presented in the words of the original investigators themselves, a technique not ordinarily (or here) characterized by its conciseness; but as the author justly remarks, "repetition may be helpful in a field of thought so complicated." Here in one volume are summarized not only the pioneer contributions of Bouguer, Pratt, Airy, Dutton, Helmert, and Hayford and the equally classic advances made by Bowie, Heiskanen, and Vening Meinesz but also the developments that have come from the studies of Barrell, Putnam, Jeffreys, Nansen, Salonen, Bullard, Glennie, and others. Here American geologists can conveniently review not only the well known results of isostatic investigations in this country and in the "negative strips" of the East and West Indies but also current knowledge about the degree of compensation beneath peninsular India, the Alps, the Rift valleys of Africa, the volcanic islands of the Pacific, and the Mediterranean and oceanic regions generally. Professor Daly is to be congratulated on having assembled this most useful compendium of the enormous literature of the subject.

The second objective which the author sets for himself is by its very nature a much more difficult one. From his review of the geodetic data, interpreted in the light of seismic and geologic evidence, he reaches a series of conclusions about the distribution of rock strength below the surface of the earth. Presumably most geologists will agree that the existence of some sort of an isostatic equilibrium in the earth's crust is no longer a matter for profitable debate and that the problems of greatest interest to-day are (a) the mechanism by which this equilibrium is attained, (b) "the vertical and horizontal dimensions of the balanced columns," and (c) the magnitude of uncompensated

[1] U. S. Geological Survey. Manuscript received, March, 1941.

loads that are supported for long intervals of time. Some of the more important conclusions reached are these.

1. Nearly all major irregularities in the earth's topography are compensated almost perfectly. However, this compensation is not local but regional—that is, the balanced columns are of the order of 50–100 kilometers in diameter.

2. A strong superficial layer, something like 40–80 kilometers thick, rests on a relatively weak asthenosphere below.

3. The Airy-Heiskanen (mountain roots) mechanism of compensation satisfies the geodetic data quite as well as, or even better than, the Pratt-Hayford (uniform depth of compensation) mechanism and is in somewhat better accord with geologic and seismic evidence. However, some combination of these two and other hypotheses is a more probable explanation than any one of them alone.

4. Largely because of small but widespread positive anomalies at sea, the actual figure of the earth appears to be more nearly that of a triaxial spheroid (one with an elliptical equator) than a spheroid of revolution. This triaxiality, if it is real, implies the existence of an irregularly shaped and therefore strong mesosphere beneath the weak asthenosphere.

5. The geologic evidence of post-Pleistocene uplift in deglaciated areas such as Fennoscandia and in the basin of old Lake Bonneville has been interpreted by geologists as the result of delicate isostatic balance in these regions. However, strictly geodetic evidence of large gravity anomalies in peninsular India and above the volcanic islands of the Pacific has been interpreted as the result of large uncompensated loads there. After considering many factors, the author concludes that these contradictory interpretations can be reconciled satisfactorily and that the asthenosphere is in reality exceedingly weak. This fifth conclusion is here stated out of its logical order because, despite its importance, it seems to this reviewer less convincing than the others.

This book is written primarily from the viewpoint of the geologist rather than the geodesist. Yet it should be added that in places the viewpoint might have been even more geologic. In a critical re-appraisal of the theory and interpretation of isostasy, greater emphasis might have been placed on the known heterogeneity of rock types and rock densities at and near the earth's surface. Because of this heterogeneity, anomalies of gravity may or may not indicate the existence of uncompensated loads. Differences in the intensity of gravity between near-by stations are being used successfully, by the methods of exploratory geophysics, to find relatively shallow irregularities of rock structure. Such features may be too small to be compensated even regionally. Nevertheless, it is essential to remember that irregularities in the vertical distribution of rock density can cause large gravity anomalies even if the total column is in perfect equilibrium. Furthermore, anomalies so caused will persist over wide areas if the irregularities of density are deep-seated or extensive. These effects of rock heterogeneity Professor Daly recognizes, of course; but the consequent uncertainty in all quantitative interpretations of gravity anomalies he seems to dismiss rather lightly.

The author also seems to underestimate the importance of geologic data when he accepts without question the mean density of 2.67 or 2.70 ordinarily used in computing the attraction of the rock mass that lies above sea-level. Because of the great areal extent and low density of sandstones and shales,

the rocks between station and sea-level in many continental areas have a mean density significantly lower than 2.67. It is true that the actual diversified conditions of nature must be greatly simplified for purposes of calculation. Yet if this simplification leads to systematic errors of considerable magnitude, its effects can not safely be ignored in reaching general conclusions about the strength of the earth's materials. Allowance for the actual densities of rock above sea-level would, in the aggregate, increase the positive anomalies in land areas and it might even eliminate much of the supposed evidence for a triaxial earth.

The type used in this book is clear and the illustrations are legibly reproduced. This reviewer found only a small number of errors of drafting, misstatements, or oversights in proof reading, and none of these is of the sort likely to cause serious misapprehension. The volume is provided with an excellent index.

ELEMENTS OF THE PETROLEUM INDUSTRY, BY MANY AUTHORS

REVIEW BY WALLACE E. PRATT[1]
New York City

Elements of the Petroleum Industry, by many authors. Published by the American Institute of Mining and Metallurgical Engineers, New York (1941). 519 pp. 6×9 inches. Cloth. Price, $5.00.

The appearance of *Elements of the Petroleum Industry* demonstrates that funds established for the general purpose of disseminating knowledge can be made to serve that purpose. The book itself demonstrates that the key men in an industry, engineers, scientists, and executives, alike, can be brought to portray themselves and their methods graphically and with benefit to their fellow workers. This double accomplishment issues from the union of financial support from the Seeley W. Mudd Memorial Fund, administered by A.I.M.E., with E. DeGolyer's energy and talent. It is only fair to add, however, that in the execution of this really formidable undertaking editor DeGolyer had the assistance of a capable advisory board, consisting of John M. Lovejoy, Hallan N. Marsh, H. H. Power, E. A. Stephenson, H. D. Wilde, and W. E. Wrather.

The *Elements* is more than elementary and it covers much more than the rudiments of the petroleum industry. Evidently the book outgrew the scope of its title, as indeed the editor admits; at any rate it is a comprehensive treatise on the chief functions of the oil industry. Its twenty-one chapters, comprising 512 pages, cover the fields of exploration, production, manufacture, transportation, and marketing. In addition there is a foreword by A. B. Parsons, secretary of the Institute, and an adequate index.

Complete as the treatment is, the reviewer believes, nevertheless, that the utility of the book would be augmented if it included a more elaborate analysis of proved reserves and discovery rates, together with a special chapter on the nature of petroleum reservoirs.

The longest chapter in the *Elements* is devoted to "The Drilling, Testing and Completion of Wells." John R. Suman, the newly elected president of

[1] Standard Oil Company (New Jersey). Manuscript received, March 20, 1941.

A.I.M.E., wrote it with the collaboration of a group (eight in number) of his fellow workers, each of whom is a specialist in one or more of the thirteen different techniques described. The treatment constitutes a veritable handbook on the subject. Like most of the other chapters, it includes an excellent bibliography. Like the rest of the book, also, it is illustrated with unusually graphic diagrams, figures, and plates.

J. E. Brantly is the author of "Oil-Well Drilling Machinery and Practices," another valuable reference work on drilling methods, including an exhaustive tabulation of drilling costs.

Walter Miller's "Petroleum Refining" will be seized upon by many readers who are not professional refiners. It is at once readable, accurate, up-to-date, and broad enough to discuss related processes, hydrogenation, polymerization, and alkylation, as well as refining proper; and to describe the manufacture of related products, rubber, solvents, and lacquers, as well as gasoline, lubricating oils, and other standard derivatives.

In "Economics of the Petroleum Industry" Joseph Pogue succeeds in presenting the industry as a whole, and each of its several functions, completely and with remarkable clarity of diction. Into his statement, "Without a dynamic technology, the industry could not have grown to its present size and importance nor supported the ramifying range of activities dependent upon it," may be read a tribute to the spirit that animates the book under review.

"Essentials for Oil Pools" reveals the results of K. C. Heald's painstaking and long-continued studies of the origin and migration of oil, the character of reservoirs, their classification, the influence of unconformities, faults and metamorphism, and the problem of the occurrence of oil, generally.

Sidney A. Swensrud traces the development of marketing through the historic periods of changing demand and analyzes current problems in distribution.

J. C. Karcher deals with "Exploration by Geophysical Methods" in such a way as to present the development of these techniques in the United States against the ample background of his own experience, both as a pioneer and a leader in that development. Along with geophysical methods, the geochemical are also described.

"Production Practice," by C. V. Millikan, states the problem of recovering oil from natural reservoirs, draws a revealing picture of the reservoir itself, and describes in detail the present-day techniques and methods in practical use in producing fields.

Allan R. Hand, in "Oil Accounting," outlines common practices in dealing with depletion, depreciation, the capitalization of exploration costs, intangible drilling costs, lease bonuses, *et cetera.* He also sketches accounting methods for pipe lines, gasoline plants, refineries, and marketing operations. Constructive criticism and extended comment reveal the author's own views and experience with all these problems.

Eugene A. Stephenson writes Chapter XIX, on "The Natural Gas Industry," presenting natural gas fully in its own particular domain as well as in its relation to the oil industry. The operation of gasoline-extraction plants is included.

Oil transportation is dealt with in two chapters: pipe lines, by W. R. Finney, and tankers, by B. B. Howard and M. D. Stauffer. Both chapters

treat of the practical problems of organizing and maintaining transportation systems: one over land, the other by sea.

"Secondary Methods for Increasing Oil Recovery," by Paul D. Torrey, is concerned largely with practice in the Appalachian fields, where secondary recovery methods are widely utilized and where the author has had extensive experience. Nevertheless, the chapter covers the field even as far as oil-mining in the Pechelbronn area of Alsace, and deals at length with theory as well as practice.

Stewart Coleman has written interestingly of "Physical and Chemical Properties of Petroleum" and its products, without making his subject too deeply chemical. The larger part of this article is devoted to the character of the principal commercial products, but the simple exposition of the nature of crude oil and its associated gases is equally informing.

The remaining chapters in *Elements of the Petroleum Industry* are all brief: none exceeds 11 pages. Several have the distinction of novelty as, for example, Rush Greenslade's "Land Tenure and Leasing"; John M. Lovejoy's "Trading and Promotion"; and "Royalties," by Alexander Deussen. It is unusual to find any published delineation of these activities. Nevertheless each is an integral function of the oil-producing industry and each is of absorbing interest.

M. Albertson writes understandingly of the problem of "Conservation," drawing upon his intimate acquantance with conservation laws and commissions to present briefly, but with clarity, proration, unit operation, and other restraints upon the free flow of oil from wells, to the end of increasing the efficiency of recovery and eliminating physical waste.

Not content with inspiring other authors to their pens, the composition of an appropriate introduction, and the further diversion of mere editing, E. DeGolyer contributes a discussion of "Direct Indications of the Occurrence of Oil and Gas," and an "Introduction to the Literature of Oil and Gas." Each of these brief chapters adds characteristic flavor to the editor's work.

RECENT PUBLICATIONS

ALBERTA

*"Development of the Athabaska Oil Sands," by Max W. Ball. *Trans. Canadian Inst. Min. Met.*, Vol. 44 (1941), pp. 58–91; 16 figs.

*"Geology of the Southern Alberta Plains," by L. S. Russell and R. W. Landes, *Canada Geol. Survey Mem. 221* (Ottawa, 1940). 223 pp., 8 pls. of fossils, 21 figs., 3 maps in pocket. Price, $0.50.

*"Preliminary Map of George Creek, Alberta," by B. R. MacKay. *Canada Geol. Survey Paper 40–17* (Ottawa, 1940). Paper sheet, 28.75×40.75 inches. Blue-line print. Geology and topography. Scale: 1 inch = 0.5 mile. Topographic contour interval, 100 feet. "Structure Sections along Lines A-B, C-D," separate sheet, 35×16.5 inches. Horizontal and vertical scale: 1 inch = 0.5 mile. Price, $0.10.

*"Preliminary Map of Grave Flats, Alberta," by B. R. MacKay. *Ibid., Paper 40–15*. With structure sections, A-B, C-D, E-F, G-H.

*"Preliminary Map of Pembina Forks, Alberta," by B. R. MacKay. *Ibid., Paper 40–16*. With structure sections A-B, C-D.

*"Preliminary Map of Bearberry, Alberta," by H. H. Beach. *Ibid., Paper*

40-19. With structure A-B. Scale: 1 inch = 1 mile. Topographic contour interval, 50 feet. Single paper sheet, 17.5 × 23 inches.

CALIFORNIA

*"Development of Miocene Production," by W. E. Dunlap. *California Oil World*, Vol. 34, No. 6 (Los Angeles, March, 1941), pp. 3-6; 3 figs., 2 tables.

CANADA

*"Canada's Fascinating Oil Business," by Max W. Ball. *Canadian Business*, Vol. 14, No. 3 (Montreal, March, 1941), pp. 34-41, 76, 78; 11 illus. Published by the Canadian Chamber of Commerce, Montreal, Canada. Price per copy, $0.25.

GENERAL

*"Index to Volumes 41 to 50." *Bull. Geol. Soc. America* (New York, March, 1941). 145 pp.

*"New Skill Will Determine Future of Oil Prospecting," by E. DeGolyer. *Oil Weekly*, Vol. 101, No. 4 (Houston, March 31, 1941), pp. 22-24.

*"Stratigraphic Exploration and Future Discoveries," by V. E. Monnett. *Ibid.*, pp. 26-30; 7 figs.

*"Technical Evolution of Petroleum Geology," by O. L. Brace. *Ibid.*, pp. 31-34.

*"Wildcat Drilling in 1940 More Successful," by Frederic H. Lahee. *Ibid.*, pp. 37-40; 2 figs., 3 tables.

*"Organization and Administration of Geological Departments," by Shirley L. Mason. *Ibid.*, pp. 41-44.

*"Geophysical Prospecting Follows Varied Patterns," by E. A. Eckhardt. *Ibid.*, pp. 45-48.

*"Geology and Economic Significance of the Northern Great Plains Basin," by Joseph A. Kornfeld. *World Petroleum*, Vol. 12, No. 3 (Hoboken, New Jersey, March, 1941), pp. 36-49, 60, 62; 9 illus.

*"Fortschritte der Reflexionsseismik" (Progress with the Reflection Seismograph), by H. Lückerath. *Oel und Kohle*, Vol. 37, No. 5 (Berlin, February 1, 1941), pp. 73-77; 9 figs.

*"Die elektrische Transient-Methode" (Electric Transient Method), by J. N. Hummel. *Ibid.*, pp. 91-94; 8 figs.

*"Possible Oil Provinces Cover Wide Area in United States and Canada," by W. V. Howard. *Oil and Gas Jour.*, Vol. 39, No. 47 (Tulsa, April 3, 1941), pp. 12-13, and 120-21; 1 map. Preview of symposium on "Possible Future Oil Provinces in the United States and Canada," led by A. I. Levorsen, chairman of Association research committee, at Houston convention, April 1.

*"Oil Exploration Has Bright Future," by W. T. Born. *Ibid.*, p. 16.

*"Wildcat Drilling in 1940," by Frederic H. Lahee. *Ibid.*, pp. 36-37; 2 figs., 2 tables.

*"Exploration Methods Combine Old and New Practices," by W. V. Howard. *Ibid.*, pp. 40-41; 3 figs.

*"The Fifth Dimension in the Oil Industry," by J. Edgar Pew. *Ibid.*, pp. 42-44, and 67. Address before the Association at Houston, April 3.

*"Measuring Particle-Size Distribution and Colloid Content of Oil-Well Drilling Fluids," by George L. Gates. *U. S. Bur. Mines R. I. 3549* (February, 1941). 21 mim. pp., 8 figs., 4 tables.

*"Slim-Hole Drilling on the Gulf Coast," by I. W. Alcorn. *Amer. Inst. Min. Met. Eng. Petrol. Tech.* (New York, March, 1941). 14 pp., 4 tables, 6 figs. *T. P. 1305.*

*"Petroleum Engineering Education," by Harry H. Power. *Ibid.*, 5 pp.

*"Science and Human Prospects," by Eliot Blackwelder. *Bull. Geol. Soc. America*, Vol. 52, No. 3 (New York, March 1, 1941), pp. 295–312. Presidential address before the Geological Society of America.

*"Permian Faunas: a Study in Facies," by Carl O. Dunbar. *Ibid.*, pp. 313–32; 8 figs. Presidential address before the Paleontological Society.

*"The Time of Origin and Accumulation of Petroleum," by F. M. Van Tuyl and Ben H. Parker. *Colorado School Mines Quar.*, Vol. 36, No. 2 (Golden, April, 1941). 180 pp., 4 figs. Prepared under the sponsorship of the research committee of the American Association of Petroleum Geologists. Price, $2.00.

HUNGARY

*"Geophysikalische Arbeiten im ungarischen Raume östlich der Donau unter besonderer Berücksichtigung von Reflexionsmessungen" (Geophysical Work in Hungary East of the Donau Reviewed by Reflection Survey), by Stephan von Thyssen-Bornemisza. *Oel und Kohle*, Vol. 37, No. 5 (Berlin, February 1, 1941), pp. 77–83; 5 figs.

IOWA

*"Outlines of Iowa Geology," by Charles Keyes. *Pan-Amer. Geol.*, Vol. 75, No. 2 (Des Moines, March, 1941), pp. 95–145; illus.

KANSAS

Oil and Gas Fields of Kansas. Map prepared by O. C. Postley, with assistance from Jane Hanna and from the State Geological Survey of Kansas. Scale, 1:500,000 (1 inch = nearly 8 miles). 32×56 inches. For sale by the director of the U. S. Geological Survey, Washington, D. C. Price, $0.50.

MONTANA AND IDAHO

*"Stratigraphy of the Belt Series in the Libby and Trout Creek Quadrangles, Northwestern Montana and Northern Idaho," by Russell Gibson, W. F. Jenks, and Ian Campbell. *Bull. Geol. Soc. America*, Vol. 52, No. 3 (New York, March 1, 1941), pp. 363–79; 3 pls., 2 figs., 2 tables.

NEBRASKA

*"Leasing in Western Nebraska Developing into Major Play," by W. V. Howard. *Oil and Gas Jour.*, Vol. 39, No. 45 (Tulsa, March 20, 1941), pp. 25–26; map and cross section.

NEW BRUNSWICK

*"Geology of Saint John Region, New Brunswick," by F. J. Alcock. *Canada Geol. Survey Mem. 216* (Ottawa, 1938). 65 pp., 4 pls. of photographs, 3 maps in pocket. Price, $0.25.

OKLAHOMA

*"Water Flooding in Oklahoma," by L. M. Arnold. *Oil and Gas Jour.*, Vol. 39, No. 47 (Tulsa, April 3, 1941), pp. 77–78; 2 figs.

ONTARIO

*"Preliminary Report on Natural Gas in Brantford Area, Ontario," by J. F. Caley. *Canada Geol. Survey Paper 40–22* (Ottawa, 1940). 31 mimeog. pp. Separate map of Norfolk County and adjacent areas, southwestern Ontario. Scale: 1 inch = 2 miles. Structure-contour interval, 20 feet. Paper sheet, approx. 29×23.5 inches.

PENNSYLVANIA

*"Ostracoda of the Middle Devonian Onondaga Beds of Central Pennsylvania," by Frank M. Swartz and Frederick M. Swain. *Bull. Geol. Soc. America*, Vol. 52, No. 3 (New York, March 1, 1941), pp. 381–458; 8 pls. of fossils, 1 table, 2 figs.

ROUMANIA

*"Gravimetric Untersuchungen und Probleme in Rumanischen Erdölgebieten" (Gravimetric Investigations and Problems in Oil Regions of Roumania), by R. von Zwerger. *Oel und Kohle*, Vol. 37, No. 5 (Berlin, February 1, 1941), pp. 83–91; 13 figs.

RUSSIA

*"On the Prognosis of Oil Deposits," by S. F. Federov. *Comptes-Rendus (Doklady) Acad. Sci. U.R.S.S.*, Vol. 28, No. 1 (Moscow, 1940), pp. 49–54; 2 figs. showing zones of comparative productivity of oil in Azerbaidjan.

TEXAS

*"Rim Rock Country of Texas," by Charles L. Baker. *Pan-Amer. Geol.*, Vol. 74, No. 2 (Des Moines, Iowa, March, 1941), pp. 81–90, illus.

TEXAS AND LOUISIANA

*"Structural Trends on Gulf Coast of Texas and Louisiana," by W. P. Jenny. *Oil and Gas Jour.*, Vol. 39, No. 47 (Tulsa, April 3, 1941), pp. 39, 49; 2 figs.

UNITED STATES

Oil and Gas Fields of the United States. Map prepared by G. B. Richardson, O. C. Postley, and Jane Hanna. Scale, 1:2,500,000 (1 inch = nearly 40 miles). 2 sheets, each 42×52 inches. For sale by the director of the U. S. Geological Survey, Washington, D. C. Price, $1.00.

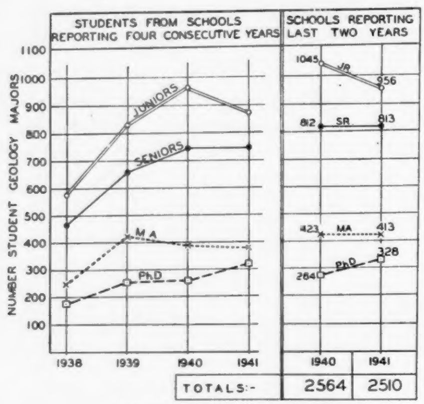
BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 25, NO. 5 (MAY, 1941), P. 910, 1 FIG.

RESEARCH NOTES

SURVEY OF GEOLOGY STUDENTS

A. I. LEVORSEN[1]

The chart shows the number of college students in the United States currently majoring in geology and shows the trend in geology majors within recent years. The four left-hand columns represent 63 colleges which reported for 4 consecutive years, thereby giving a common basis for measuring the trend in enrollments. The two right-hand columns represent 74 colleges which have reported for the past 2 years and probably reflect 95 per cent of the total registrations in geology in the United States in the various classes listed. Thus, in the past 2 years there has been a decline in the number of Junior majors and an increase in the number who are past the M.A. degree and are working toward the degree of Ph.D.



STUDENTS, WHO UPON LEAVING SCHOOL, ENTERED THE FIELD OF:-

YEAR	PETROLEUM	OTHER
1938	230	239
1939	297	312
1940	255	365

GEOLOGY STUDENTS IN THE U.S.

The lower position of the chart shows the relative placement of those leaving school and whose employment is known at their last school location. Thus, of those leaving school during the year 1940, and who reported their location back to their school, 255 went into the petroleum industry while 365 went into other lines of work, including further graduate work at other colleges. This represents a decrease in the percentage of those entering the petroleum industry as compared with previous years and may be the cause of the increase in those working towards a Ph.D. degree in 1941.

This survey is made each January by the research committee and it is planned to continue making it during the years to come.

[1] Chairman, research committee.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 25, NO. 5 (MAY, 1941), PP. 911-990, 11 FIGS.

THE ASSOCIATION ROUND TABLE

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following candidates for membership in the Association. This does not constitute an election but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it promptly to the Executive Committee, Box 979, Tulsa, Oklahoma. (Names of sponsors are placed beneath the name of each nominee.)

FOR ACTIVE MEMBERSHIP

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D. B. Winfrey, Stuart Mossom, Thornton Davis
George Richard Heyl, Little Rock, Ark.
J. O. Nomland, Leonard W. Henry, L. L. Tabor
Frank Edward Ittner, Bakersfield, Calif.
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Edgar Estes Martin, McAllen, Tex.
Paul W. McFarland, F. H. Lahee, F. E. Heath
Edwin D. McKee, Flagstaff, Ariz.
Ian Campbell, Albert Gregersen, Vincent W. Vandiver
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Lloyd A. Nelson, El Paso, Tex.
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Homer Eugene Roberts, San Antonio, Tex.
P. J. Rudolph, O. S. Petty, D. B. Winfrey
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Albert Martin Sullivan, Jackson, Miss.
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Thomas Henning Green, Tulsa, Okla.
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George Marvin Jenkins, Tupelo, Miss.
Chalmer J. Roy, Harold N. Fisk, Henry V. Howe
Wilber Judson, Newgulf, Tex.
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Clinton A. Lueth, San Antonio, Tex.
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Benjamin Herbert Martin, Houston, Tex.
Don L. Benson, R. L. Beckelhymer, Merle C. Israelsky
Holland C. McCarver, Medan, Sumatra, N.E.I.
E. T. Nichols, J. P. Fox, R. H. Cuyler
William Albert McMorris, Tulsa, Okla.
Dollie Radler Hall, E. A. Wyman, J. V. Howell
Albert Melsheimer, Sulphur, La.
R. Dana Russell, H. V. Howe, Chalmer J. Roy
John B. Miller, Bogota, Colombia, S.A.
J. O. Nomland, Leonard W. Henry, W. E. Heater
Edward Monsour, Shreveport, La.
Harold N. Fisk, James H. McGuirt, Chalmer J. Roy
Louis J. Regan, Jr., Los Angeles, Calif.
Ian Campbell, John H. Maxson, F. D. Bode
Joseph Robinson, Springfield, Mass.
E. H. Stevens, F. M. Van Tuyl, J. Harlan Johnson
George Russell Schoonmaker, Casper, Wyo.
C. J. Hares, M. M. Fidlar, John R. Fanshawe
Lynn Burdeaux Trombla, Bakersfield, Calif.
Art R. May, Walter A. English, E. C. Simpson
Arthur Benbrook Van Tine, Amarillo, Tex.
H. B. Fuqua, B. E. Thompson, J. B. Lovejoy
Andres Lopez Vazquez, Coatzacoalcos, Vera Cruz, Mex.
Charles E. Decker, W. M. Plaster, J. W. Hoover
Albert Hodges Wadsworth, Jr., Bay City, Tex.
Fred M. Bullard, Hal P. Bybee, Robert H. Cuyler
Richard Wasem, Long Beach, Calif.
Ian Cmpbell, John P. Buwalda, Francis D. Bode
John Schiller Wold, Vanderbilt, Tex.
S. A. Thompson, William W. Clawson, John E. Van Dall
Harold A. Wolverton, Lake Charles, La.
Dean Metts, W. R. Canada, Hillard W. Carey
Albert Wynn, Wichita, Kan.
D. A. McGee, V. E. Monnett, C. E. Decker

FOR TRANSFER TO ACTIVE MEMBERSHIP

Charles Samuel Agey, Wichita, Kan.
Dollie Radler Hall, A. R. Denison, Robert L. Cassingham
Meyer Michael Allon, Duncan, Okla.
Samuel W. Riter, W. E. Bernard, Clyde G. Strachan
Benjamin Franklin Baldwin, Tulsa, Okla.
F. H. Schouten, John G. Bartram, H. T. Morley
Jules Braunstein, Houston, Tex.
W. S. Adkins, J. B. Dorr, S. W. Lowman

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Wayne Z. Burkhead, Houston, Tex.
O. L. Brace, A. L. Selig, Shirley L. Mason
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John R. Crump, Midland, Tex.
B. E. Thompson, C. D. Cordry, H. M. Bayer
Joseph Horace Deming, Houston, Tex.
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Thomas Wilson Dibblee, Jr., Santa Barbara, Calif.
Elmer R. Baddley, H. W. Hoots, E. R. Atwill
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REMARKS AT THE FIFTY-THIRD ANNUAL MEETING OF THE GEOLOGICAL SOCIETY OF AMERICA

L. C. SNIDER[1]
Austin, Texas

I wish to express on behalf of all the members of the American Association of Petroleum Geologists our sincere appreciation of the cordial invitation extended to us by the Geological Society of America to take part in its fifty-third annual meeting, and I am sure that our members have responded to this invitation in sufficient numbers to make this statement on my part almost, if not quite unnecessary.

The association is now a little less than one-half as old as the Society, but we are improving rapidly in this respect: twenty-five years ago we were less than one twenty-fifth as old, and in twenty-five more years we will be practically three-fourths as old, and in another quarter of a century the difference in our ages will scarcely be noticeable.

From its inception, the Association has been a professional society devoted to the exploratory and exploitation divisions of the petroleum industry. At the same time, we believe that we have maintained high standards of scientific training and attainments as prerequisites to membership, and that our contributions to the more purely scientific aspects of geology are such as to justify the pride that we take in them. Also we have no feeling of having degraded our science by applying it to the practical end of finding petroleum and natural gas and of improving methods of searching for and producing these substances so vital to our present stage of existence. We have interpreted the term "petroleum geology" in a broad sense, and believe that many of the published contributions in the *Bulletin* of the Association and in its special volumes are good geology, not necessarily impaired by the fact that they were produced by petroleum geologists.

The field of petroleum geology has itself broadened almost unbelievably in the quarter-century of the Association's existence. At first, practically all petroleum geologists fitted the somewhat derisive name of "rockhounds" applied to them by other divisions of the petroleum industry. Our principal activity was the search for structures favorable for the accumulation of petroleum and natural gas where these could be located by the mapping of outcropping strata. In a few years, however, this purely surface work was supplemented by subsurface studies—the collection of cuttings and cores from drilling wells, and the office study of these by microscopic and other methods. The use of heavy minerals and of micro-fossils was a logical development which soon followed the mere physical and chemical examination of cuttings and cores. The use of complex and delicate geophysical instruments for the determination of the specific gravity, the behavior toward vibrations, and the magnetic and electrical properties of subsurface rocks began several years ago and has increased almost uninterruptedly until the present. Many members of the American Association of Petroleum Geologists are really highly specialized geophysicists using the torsion balance, magnetometer, gravimeter, various forms of the seismograph, and instruments for the electrical and radio-

[1] President of the American Association of Petroleum Geologists. Remarks at the opening session of the fifty-third annual meeting of the Geological Society of America, Austin, Texas, December 26, 1940.

active logging of wells. Still more recently geochemistry has made a bid as a tool for petroleum and natural gas exploration and investigation along this line is active. Along with this diversification of scientific fields of interest in petroleum geology, there has been an areal separation into more or less distinct groups within the Association, for each petroleum-producing district has its own peculiar geologic problems.

Naturally, this great diversification in scientific and geographic fields has been accompanied by a rapid increase in the number of workers in the broad field of petroleum geology. There are at present practically 3,500 members of the Association, which in itself is conclusive evidence of the interest in, and development of, the field of an organization only twenty-five years old.

The particular scientific fields of interest have been cared for by the development of groups within the Association, namely, the Society of Economic Paleontologists and Mineralogists which is a division of the Association, and the Society of Exploration Geophysicists, which was first an independent organization, later a division of the Association, and still later resumed an independent status though still retaining affiliation with the Association. Both of these societies hold their annual meetings concurrently with that of the Association.

Geographic variations in interest are cared for by local societies distributed from Charleston, West Virginia, to Los Angeles, California, and from Alberta to South Texas. Twenty-two such societies are affiliated with the Association. Affiliation technically means little more than an expression of mutuality of interest, and the approval of the constitution and by-laws of the local society by the executive committee of the Association. The South Texas Geological Society and the Pacific Section are sections of the Association, a relationship somewhat closer than affiliation, though still leaving the local groups practically independent.

Actually, the relationship between the Association and the sections and affiliated societies is much closer than is indicated by a strict interpretation of the conditions of affiliation. For example, affiliated societies in or near the larger cities act as hosts to the Association for most of its annual meetings, as the Illinois Geological Society did at Chicago in 1940, and the Houston Geological Society will do in April, 1941.

One of the projects of the Houston Geological Society in connection with the April meeting at Houston is to acquaint members, by means of exhibits, with what is being done in different areas and different lines of work. A committee, under the chairmanship of Paul Weaver, has already assembled a number of exhibits contributed by different groups and Mr. Weaver has brought to Austin and installed for display at a convenient location on the campus some of these, which we believe will repay inspection and study by those attending this meeting. Exhibits on display here have been contributed by the Houston, South Texas, South Louisiana, West Texas, and Fort Worth geological societies.

It is evident that the speaker has worked himself around from the position of acknowledging an invitation to the American Association of Petroleum Geologists to the fifty-third annual meeting of the Geological Society of America to that of inviting the Fellows of the Society to inspect exhibits prepared for the Association by one of its sections and four affiliated societies. I believe that no apology is necessary for this about-face, since several here are able and

willing to change instantly from guest to host, or *vice versa*, on a moment's notice, or, indeed, even without notice. In order to maintain such a satisfactory condition, I wish to conclude my expression of appreciation on behalf of the American Association of Petroleum Geologists, at being invited to attend this meeting of the Geological Society of America, with a hearty invitation, also, I am sure, on behalf of the whole membership of the Association, to the Fellows of the Society to attend our twenty-sixth annual meeting at Houston, Texas, during the first week of April, 1941.

TWENTY-SIXTH ANNUAL MEETING

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS RICE HOTEL, HOUSTON, TEXAS

APRIL 2–4, 1941

The American Association of Petroleum Geologists met in twenty-sixth annual convention at Houston, Texas, March 31, April 1, 2, 3, 4, and 5. This full business week is twice the duration of the officially designated dates of April 2–4, but it is impractical for this Association of 3,500 geologists, represented in annual meeting by more than 1,000 members, to attempt to present its technical program and to discuss its special research problems in the brief course of three days.

The Houston meeting illustrated the modern petroleum geologist's conception of a geologists' convention: it gathered into one the meetings of the Society of Economic Paleontologists and Mineralogists, the Society of Exploration Geophysicists, and the American Association of Petroleum Geologists. It consummated the plans and efforts of Alexander Deussen, general chairman, and his assisting committees. It pictured the largeness of geology in the petroleum industry; it illustrated the variety and completeness of the activity of the petroleum geologist in his comprehensive character as earth scientist in the search for oil and gas: paleontologist, stratigrapher, geophysicist, geochemist, map-maker, production engineer; indeed, as explorer, producer, administrator, executive. The registration cards showed 131 members of the S.E.P.M. and 305 members of the S.E.G. present.

Two thousand eight hundred and one persons registered at this convention: 1,043 were full members, 166 were associate members, 827 were non-member men, and 765 were non-member women. This was the largest attendance in Association records. The largest previous meeting was in 1939, at Oklahoma City, where 1,858 persons registered. The registration from Houston alone included 1,086 geologists, wives, and friends, obviously explaining the phenomenal record. No other city claims so many resident geologists. Texas registrations totaled 1,880. Without Houston, the total convention attendance was 1,715.

The registration of members and associates by states as compared with the total number of members and associates residing in the respective states is shown in the following tabulation.

Active, or full, members present at the meeting numbered 1,043, of which 959 were qualified to vote in the presidential election; 548 voted.

All meetings of the three societies were held on the Mezzanine of the Rice Hotel. The same hotel was convention headquarters for the same groups in

Courtesy, Houston *Chronicle*

Houston Geological Society committee on convention arrangements.

Seated, left to right: C. D. Lockwood, *Lockwood's Daily Oil Report*, publicity; J. A. Culbertson, Continental Oil Company, field trips; George Sawtelle, Kirby Petroleum Company, entertainment; Alexander Deussen, steering committee; Ben C. Belt, Gulf Oil Corporation, finance; George S. Buchanan, president of Houston Geological Society; Wayne F. Bowman, invitations.

Standing: Carleton D. Speed, Jr., Speed Oil Company, reception; Olin G. Bell, hotel and registration; Al Ferrando, Standard Oil Company of Texas, golf; O. L. Brace, sub-chairman, technical program; W. A. Clark, Jr., Schlumberger Well Surveying Corporation, laboratory tours; K. H. Crandall, Standard Oil Company of Texas, transportation; T. I. Harkins, Independent Exploration Company, geophysical; Perry Olcott, Humble Oil and Refining Company, technical program; Marcus A. Hanna, Gulf Oil Corporation, S.E.P.M.; Wallace C. Thompson, General Crude Oil Company, past-president, Houston Geological Society.

Photograph by Colorgraphic Arts, Inc

Group of committeemen of Houston Geological Society expressing satisfaction with registration and other convention arrangements. The 2,801 names and local addresses were transferred from the registration cards to the visual record on the easels by courtesy of Postal Telegraph.

Left to right: George S. Buchanan, president, Houston Geological Society; Olin G. Bell, chairman of registration and hotels; J. A. Culbertson, chairman of field trips; Alexander Deussen, general chairman; Perry Olcott, chairman of technical program; Wallace C. Thompson, past-president, Houston Geological Society, steering committee; J. M. Bugbee, exhibits committee.

	Total Members and Associates in State	*Registered at Convention*		*Total Members and Associates in State*	*Registered at Convention*
Texas	1,164	759	New York	92	15
Oklahoma	459	146	Pennsylvania	66	8
Louisiana	186	93	Indiana	52	7
California	424	40	Arkansas	15	6
Kansas	138	35	New Mexico	24	6
Colorado	46	17	Dist. Columbia	41	5
Illinois	123	17	Missouri	24	5
Mississippi	33	16	Ohio	23	5
			Other states and countries	564	39
			Total	3,474	1,209

1933 when only one-third the attendance of the 1941 gathering seemed to crowd the floor space. Extending across the far side of the Rice's handsomely remodeled Lounge, Olin Bell's reception counter bore the surge of incoming people, holding them in three alphabetical groups while they registered and received an ample envelope of printed matter, in particular: (1) Perry Olcott's pocket-size 68-page program containing the convention schedule of events and abstracts of the technical papers of both A.A.P.G. and S.E.P.M.; (2) a large-page pamphlet of structure maps and cross sections entitled, "An Introduction to Gulf Coast Oil Fields," prepared by the Houston Geological Society, showing guide fossils of the Texas Gulf Coast, and a diagrammatic dip section and seven types of oil-field structure in the Houston district; (3) a copy of *Bull-et-al*, a 28-page miniature take-off of the familiar cream-covered *Bulletin* of the A.A.P.G., in lighter vein, containing "A Rogues' Gallery" of the Houston Society and much well worded information about local diversion and education, and illustrated by the black-and-white art of Joe Wilson, now of Dallas; and (4) a mimeographed list of laboratory tours in the city. Tickets were on sale for field trips, city tours, breakfast-dance, ladies style show, college and company luncheons. Each person made his own choice. There was no registration fee.

From this center of information the crowd was diverted on the one hand toward the West Foyer leading to the sessions of the geophysicists in the South American Room, the paleontologists in the Lacquer Room, and to the various committee rooms, and on the other hand toward the East Foyer and the general sessions of the A.A.P.G. in the Ball Room.

Both foyers, the Sam Houston Room, and all other available space not occupied by the milling throng were lined with booths of oil-field, laboratory, and technical-equipment companies. Purely educational, scientific exhibits under the supervision of Paul Weaver overflowed their originally planned 700 square feet and occupied as much more space scattered in the several committee rooms.

On Monday, March 31, the registration counter opened for business, and recorded seven hundred names though two executive committee meetings were the only apparent incentives for attendance.

On Tuesday, April 1, the attendance rapidly increased to more than a thousand, attracted by the annual meetings of standing committees, opening of the S.E.G. sessions, and the A.A.P.G. research conference groups followed by the research committee dinner and round-table discussion under the guidance of A. I. Levorsen. The conference group subjects were: "Sedimenta-

Photograph by Colorgraphic Arts, Inc.

Twenty-sixth annual meeting of the Association, Houston. Joint technical session with S.E.P.M. and S.E.G., Ball Room, Rice Hotel, April 3, 1941.

Photograph by Colorgraphic Arts, Inc.

Group on rostrum at joint session of A.A.P.G., S.E.P.M., and S.E.G., Rice Hotel, Houston, April 3.

Front row, left to right: Robert E. Wilson, president, Pan American Petroleum and Transport Company, and in charge of Petroleum Section, Raw Materials Division, Advisory Commission to Council of National Defense; W. T. Born, president, 1940–1941, Society of Exploration Geophysicists; E. DeGolyer, past-president, A.A.P.G., H. Wiess, president, Humble Oil and Refining Company.

Back row, left to right: Carey Croneis, president, 1940–1941, Society of Economic Paleontologists and Mineralogists; John R. Suman, vice-president, Humble Oil and Refining Company; L. P. Garrett, past-president, A.A.P.G., J. Edgar Pew, vice-president, Sun Oil Company; A. J. Galloway, vice-president, Shell Oil Company, Inc.; Sumner T. Pike, commissioner, Securities and Exchange Commission; N. C. McGowen, president, United Gas Pipe Line Company and Union Producing Company; J. Sayles Leach, vice-president, The Texas Company.

tion and Reservoir Rocks," "Origin and Evolution of Oil," "Migration and Accumulation of Oil," "Relation of Oil Analyses to Stratigraphy," and "Oil-Field Waters." The round-table symposium was held at night in the Ball Room: "Possible Future Oil Provinces of the United States and Canada." Such subjects, with able leadership, have attracted larger attendance each succeeding year,—more than a thousand on this "pre-convention" day at Houston.

On Wednesday, the first day of the A.A.P.G. technical program, the S.E.P.M. and the S.E.G. were also conducting prepared technical sessions and the registration broke the previous maximum annual meeting record, passing the 2,000 mark. Nominations for officers were made from the floor in the first session of the annual business meeting. The style show for the ladies jammed the roof garden of the hotel.

On Thursday, April 3, the three presidential addresses and the four special addresses, stressing the national aspect of petroleum and petroleum geologists, filled the Ball Room to the point of standing room only, and overflow groups listened to the program brought out of the Ball Room by extension amplifiers. The attendance was on its way to the 2,800 mark. More badges and registration supplies were hastily ordered. Ballot boxes were open all day for the election of president, but most of the voters were elsewhere, listening to papers, meeting friends, visting the Hockley Salt Mine, flying over the city, attending college renunion luncheons, looking at exhibits. More than seventeen hundred people attended the dance and stayed for breakfast after the floor show. Entertainment chairman George Sawtelle surpassed his own optimism.

On Friday, the registration counter passed out the last program, pinned on the last substitute badge, counted the cards, and tried to believe the final figure: 2,801 geologists, wives, and friends, a record probably to stand for a number of years. At the annual business meeting, held on Friday afternoon instead of Friday morning, in consideration of the previous night's dance and entertainment, the Association again decided by a vote of 2 to 1 to retain the present method of selecting officers: by nomination from the floor in open meeting and by ballot vote of active members not in arrears for dues and in attendance at the meeting. The annual golf tournament for the Bostick cup was held at Brae Burn Country Club; there were field trips to see Galveston Bay water drilling and the Hockley Salt Mine, and tours through Houston research laboratories.

On Saturday, April 5, the big meeting was history, the last field trip was being conducted to oil fields, salt and sulphur domes, and the last exhibit booth was being dismantled, but in one of the committee rooms, away from the litter of papers and the noise of hammers and crates, one specially called research group of geologists, chemists, and physicists continued in conference all day, laying plans for a renewed attack on the old, old problem, "The Origin of Oil."

In retrospect, each person holds in mind or heart one scene, event, or conversation, serving for him the key that unlocks other memories and thus reopens all the rooms connecting all events of the combined occasion. For one, the sesame may be the scene of many sparkling tables on the terrace of the Rice Hotel, in the early evening of the breakfast dance, before the low first-quarter moon had disappeared beyond the city's sky line, yet late enough to

feel the rhythmic beat and full emotion of "The Eyes of Texas Are Upon You," sung with the firm round voices of young alumni.

And so the explorers for oil convened; filled the meeting places to overflowing; read papers; compared notes; acquired new ideas, scientific, practical, economic; jostled and elbowed in the biggest convention yet, and liked it,—geologists, paleontologists, geophysicists, all gathered in one place in common work and purpose; and went away, each with his own treasured memory of another annual meeting.

GOLF TOURNAMENT

Following are the pertinent facts concerning the annual golf tournament as reported by Al Ferrando, chairman of the golf committee.

The annual golf tournament for the J. Wallace Bostick Cup was held at the Brae Burn Country Club on Friday, April 4. Ninety members and guests participated—the largest turn-out in our history. Besides the Bostick Cup, several prizes consisting of golf equipment were awarded. The net scores were based on a "blind handicap" computed from the nine even holes as predetermined by the golf "pro" at Brae Burn, but not divulged until after completion of play.

The member winner in the Bostick tournament was Gentry Kidd with a low gross score of 77. The guest winner of the Bostick Cup was Louis Douglass with a low gross score of 74. Other prize winners were as follows.

	Score
2nd low gross (member)—Tie: Jack Chambers and Al Ferrando	78
2nd low gross (guest)—R. E. Mills	76
Low net—W. A. Clark	96—66
2nd low net—Gordon Atwater	97—67
3rd low net—Tie: Charles Daubert, H. B. Fuqua, Jerry Smiser, Oscar Walton, Dean Metts, H. L. Miller, B. W. Allen	Net—71
High net—Don Goodwill	Net—88
Eagle (member)—Ed Dawson	

ELECTION

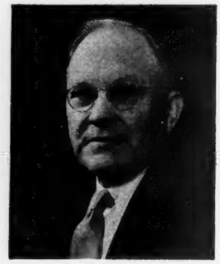
Officers elected for the new administrative year beginning immediately after the Houston meeting are: president, Edgar W. Owen, of the Lew H. Wentz Oil Division, San Antonio, Texas; vice-president, Earl B. Noble, of the Union Oil Company of California, Los Angeles, California; secretary-treasurer, Edmond O. Markham, of the Carter Oil Company, Tulsa, Oklahoma; editor, Walter A. Ver Wiebe, of the University of Wichita, Wichita, Kansas.

The Society of Economic Paleontologists and Mineralogists elected these officers: president, Henry V. Howe, University of Louisiana, Baton Rouge, Louisiana; vice-president, Alva C. Ellisor, Humble Oil and Refining Company, Houston, Texas; secretary-treasurer, Henryk B. Stenzel, Bureau of Economic Geology, Austin, Texas.

The Society of Exploration Geophysicists elected: president, H. B. Peacock, Geophysical Service, Inc., Houston, Texas; vice-president, Frank Goldstone, Shell Oil Company, Inc., Houston; secretary-treasurer, William M. Rust, Jr., Humble Oil and Refining Company, Houston; editor, R. D. Wyckoff, Gulf Research and Development Company, Pittsburgh, Pennsylvania.

President
EDGAR W. OWEN
San Antonio, Texas

Vice-President
EARL B. NOBLE
Los Angeles, California



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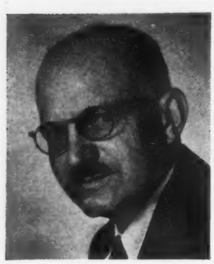

S.E.P.M. President
HENRY V. HOWE
Baton Rouge, Louisiana

S.E.G. President
H. B. PEACOCK
Houston, Texas

Officers elected at the Houston convention

(Photograph of Owen by Haddow-Marquis; Noble by Curtis Wilshire Studios; Howe by Fonville Winans)

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ABSTRACTS OF PAPERS ON HOUSTON PROGRAM

Gulf Coast

1. O. L. Brace, consulting geologist, Houston, Texas
Review of Developments in 1940, Gulf Coast of Upper Texas and Louisiana

The poor discovery record of the upper Texas Coast for 1940 is no improvement over that established for 1939. Coastal Louisiana, however, showed an advance in both the number and quality of new areas uncovered. The most noteworthy improvement of the year in Louisiana has been the increasing importance of the new reserves added to old fields through extensions and new sand discoveries.

During the past few years, a shift in the center of successful activity has given coastal Louisiana the lead over upper Texas. This shift coincided with the opening of the large area of only partly explored delta territory of Louisiana to intensive exploitation.

The increase in the number of economically marginal areas that are now being developed is credited to improvements in the technique of well testing and completion, mainly the introduction of the electric log, gun perforating, and cement squeezing.

2. Urban B. Hughes, consulting geologist, Jackson, Mississippi
Developments in Mississippi in 1940

Development in Mississippi during 1940 passed through two phases. The first of these was hysterical, resulting from the fact that only a few of the major companies and independent operators had scientific data or lease protection prior to the discovery at Tinsley. This resulted in rapid, and necessarily sketchy, geophysical work, promiscuous leasing and drilling of wells by crews largely inexperienced in Gulf coastal formations. In the second phase, hasty, haphazard work gave way to sounder practices in both exploration and drilling.

During the first half of the year leasing activity was largely confined to the north portion of the state but during the latter months the play shifted to the south. The 1,221,412 acres of leases owned by major and larger independent oil companies on January 1, 1940, was increased to 4,775,619 acres during the year. A probable additional 1,500,000 acres were acquired by individuals and small independents in the same period.

On January 1, 1940, there were 61 geophysical parties operating in Mississippi. This figure was increased to 64 on June 1, and decreased to 22 on the last day of the year. At the peak, more than 60% of all geophysical parties were operating in the State.

No new discoveries of importance occurred. The Pickens field, with four producers, proved disappointing. Tinsley spread beyond early expectations and had 101 producing wells.

Of the 208 wells drilled, 103 were dry holes and of these only seven resulted in positive proof of the existence of structure. Many of the dry holes were drilled without geological guidance or were located on geophysical evidence which was unsatisfactory, and some were drilled on seemingly good prospects which were disproved by drilling.

One of the main purposes of this paper is to evaluate the results outlined above and to point out their influence on future activity. Although the results of exploration during the year 1940 were disappointing, a true valuation leads to the conclusion that the State has not had a fair test, especially in the southern part, and that its future potentialities as an oil-producing area have not been materially affected.

3. Tom McGlothlin, Gulf Oil Corporation, Jackson, Mississippi
Notes on Geology of Mississippi

The larger structural features of Mississippi include: the Issaquena-Sharkey "Platform," an eastern extension of the Monroe-Richland uplift, the salt basin, the Jackson structure, and the George and Stone County "high."

Sediments that crop out in Mississippi or that have been reached by drilling wells range in age from Ordovician to Recent. The general stratigraphy of the post-Paleozoic beds is herein discussed.

The extensive truncation of the Comanche series with the overlap of the Gulf series is not as noticeable in Mississippi as it is in South Arkansas and Louisiana. Apparently the beds of the Upper and Lower Cretaceous are more nearly parallel in Mississippi.

A structure map and several cross sections are presented.

4. Carl B. Richardson, Barnsdall Oil Corporation, Houston, Texas
Comparative Study of Origin and Distribution of Gulf Coast Tertiary Sediments

The Tertiary sediments of the Gulf Coast offer the world's finest available laboratory for a broad study of sedimentation. The deep drilling of the past few years furnishes accurate logs and samples to a depth of about two miles over a large area of relatively undisturbed sediments. The Gulf of Mexico with its shorelines parallel to the strike of the sediments offers a present example of processes and distribution which may be compared to the past.

The bottom sample descriptions from Coast and Geodetic Survey charts have been compiled on a map of the Gulf of Mexico. The shape of the Gulf bottom based upon soundings has been studied with respect to the action of currents and waves upon distribution of sediments. The following zones of deposition are outlined and discussed: continental, lagoonal, the sand zone, the mud zone, the coral zone, and the deep sea muds.

Four cross sections, exaggerated 20 times vertically, have been drawn from the Cretaceous outcrop across the Gulf. The profiles of the Gulf which accompany the subsurface section relate the present sedimentary zones to those of the past. The detail of the subsurface sections shows a comparison of the various sand groups as to distribution, volume, extent, and probable effects of deltas, currents, and waves. Compared to one another, the sections show the type and relative amount of deposition on different parts of the Gulf Coast and place the time and location of the outstanding depositional events.

5. C. B. Roach, Shell Petroleum Corporation, Lake Charles, Louisiana
Subsurface Study of Jennings Dome, Acadia Parish, La.

A study of the subsurface structure of the flank sediments of the Jennings dome has revealed several stages of uplift of the salt plug which have resulted in erosion and subsequent unconformities. One such uplift at the end of *Marginulina* times is of great importance, as it closed a period of intense faulting which does not extend into the overlying sediments. It is therefore extremely difficult, if not impossible, to predict the structural conditions which will be encountered in the *Marginulina* oil sand series when drilling. Faulting of fairly recent age is also present, which cuts both the Miocene and Oligocene sections.

The origin of the mineralized Miocene sand section on the east half of the dome is also discussed, together with the effect of these hard cemented sands upon the growth of the salt plug. This further indicates the manner in which the oil migrated to the supercap sands.

6. S. RUSSELL CASEY, Woodley Petroleum Company, Houston, Texas, and RALPH B. CANTRELL, Lane-Wells Corporation, Houston, Texas
Davis Sand Lens, Hardin Field, Liberty County, Texas

The Davis sand lens of the Hardin field is a buried off-shore barrier (bar). It is in the upper Saline Bayou member of the Yegua (upper Eocene) formation.

The sand was first recognized as a separate sand in the Woodley Petroleum Company's Emma Davis well No. 1; the sand was encountered at a depth of 7,511 to 7,525 feet. Two wells are now producing gas and distillate from this sand, and one well is producing 36° oil. It is a separate and closed reservoir.

An isopach map of the interval containing the Davis lens shows a marked thickening within the area where the best development of the Davis sand is found. It discloses that the bar along its long axis is approximately 9,400 feet in length, and the width varies from approximately 300 feet to 1,200 feet. The total area covered by the lens is approximately 250 acres. The contours of the isopach map are lines of sedimentation from which the section to be penetrated may be postulated in advance of the drill.

The Davis "zone," wherein the lens is found, is composed of alternating sand, sandy shale and shale, and is arenaceous in character indicating lagoonal or tidal-flat deposition. The main sand is a medium-grained quartz sand, containing few other minerals, as compared to the finer-grained, more mineralized sands of the Yegua formation.

The lens was laid down as a barrier beach or off-shore bar by a retreating Yegua sea.

7. MICHEL T. HALBOUTY, consulting geologist, Houston, Texas
Oil and Gas Stratigraphic Reservoirs in University Oil Field, East Baton Rouge Parish, Louisiana

The University field, East Baton Rouge Parish, Louisiana, is a deep-seated domal type structure with minor faulting.

Production from the field is obtained from Miocene sands. The main and most important oil-producing horizon is the 6,400-foot sand. Other producing sands are the 4,300-foot gas sand, the 6,700-foot oil sand and the 7,100-foot gas sand. Aside from these four producing horizons, there are three sands which are potentially productive, the 4,100-foot and 6,200-foot sands in which oil has been cored, and the 6,900-foot sand carrying gas. To date, no attempt has been made to produce from these latter sands.

This field is of particular interest because of the presence of a greater number of stratigraphic traps (oil and gas reservoirs) than are known in any other field of the Gulf Coast except in piercement-type domes.

Accumulation in the productive 4,300-foot sand, and in the 4,100-foot and 6,200-foot potentially productive sands is controlled by stratigraphic factors which created traps.

Individual contour maps on these three sands delineate their respective lines of pinchout and with the assistance of cross sections of the sands in the field, provide an accurate picture of the stratigraphic traps which they form. An hypothesized explanation based on the assumption that erratic contemporaneous deposition of sediments from different sources in the same area is given.

8. DOROTHY A. JUNG, Republic Production Company, Houston, Texas, and DORIS S. MALKIN, Speed Oil Company, Houston, Texas
Marine Sedimentation and Oil Accumulation on Gulf Coast

The marine sands of the Gulf Coast are prolific petroleum reservoirs. Deposition of these sands has taken place during a series of advances and retreats of the sea. A résumé of the sedimentation and depositional conditions occurring in a marine advance, or transgression, and in a marine retreat, or regression, is presented. The resulting stratigraphic sequences, the "marine overlap" and "marine offlap" are discussed under ideal conditions, and illustrated by electrical log profiles. Particular reference is made to possibilities for petroleum accumulation as influenced by stratigraphic conditions.

Sands deposited in a transgressive sea, such as the "Cockfield," upper Wilcox (Sabinetown), *Marginulina*-upper Frio, and lower Miocene sands, are believed to present conditions favorable for the migration, accumulation, and recovery of oil. Although sands deposited in a regressive sea, such as parts of the Rockdale (Wilcox), lower Yegua, Vicksburg-lower Frio, and Catahoula, are not considered theoretically as favorable, local structural or environmental conditions may effect excellent reservoirs.

The compound features representing a marine invasion followed by a retreat, or the reverse, are also considered and electrical log profiles presented. The economic significance in petroleum geology of the resultant sand wedges and shale wedges is dis-

cussed. It is suggested that both local and regional studies of producing horizons be made in the light of the theory of the "marine overlap."

9. Clarence E. Brehm, consulting geologist, Mt. Vernon, Illinois
Pickens Pool, Yazoo County, Mississippi

The Pickens pool was discovered by continuous profiling seismic work which showed an increase of closure with depth. This increase, causing four times as much reversal on the Eutaw as on the Midway, has been substantiated by drilling.

The "pool" consists of four wells producing 4–8 feet of saturated Wilburn sand in the Eutaw over approximately 160 acres. The producing area is practically defined by dry holes. Wells come in for 400 barrels, settle to a steady 200 barrels on pump. Production to date is 300,000 barrels.

The limited producing area suggests a small structure but an isopach of the Wilcox formation shows it to be in the center of an area of structural thinning extending 30 or 40 miles parallel to the Yazoo basin.

The break in seismic reflections near the field is interpreted as a fault extending into the Lower Cretaceous. It is suggested that the original reservoir was in those lower beds and that some oil migrated up the fault plane to impregnate this small area of the Wilburn sand. This condition is compared with the faulted Tinsley field and Upper Cretaceous fields of northern Louisiana and southern Arkansas.

10. A. N. Wilson, General Crude Oil Company, Houston, Texas
Basal Vicksburg Sand of Texas Gulf Coast

The discovery of commercially important oil sands at the base of the Vicksburg formation, on the flanks of some Texas Gulf Coast dome structures during the past few years, recalls the necessity for constant re-examination of the older producing areas by methods which make full use of the newest proved geological tools.

This paper employs the now common electrical well log, in conjunction with the best paleontological opinions, to identify and to map the areal extent and thickness of the basal Vicksburg sand in the Texas Gulf Coast, and to predict, with some foundation, its future possibilities for commercial oil production on the older known structures.

Electrical well log cross sections through the region, two of them down the dip and one along the sedimentary strike, are given in support of the sand thickness map.

11. Joseph M. Wilson, Dallas, Texas
South Cotton Lake Field of Chambers County, Texas

Torsion-balance work in 1934 indicated a large minimum which centered, after regional corrections were applied, slightly north of the present producing area. After two wells were drilled in the vicinity, both of which were abandoned after encouraging showings, the area was detailed with the reflection seismograph, using the continuous profile method. As the result of this work, the discovery well was located and subsequent development of the field showed that the seismograph gave a remarkably accurate picture of the structure, a faulted dome elongate east and west.

The three producing sands are the *Marginulina* sand with an average of 7½ feet of effective sand, the No. 1 Frio with 10 feet and the No. 2 Frio with 5 feet. Each sand has a separate water level and oil-gas contact and all occur within an interval of about 100 feet. The average total depth of wells is 6,500 feet. The maximum producing area is expected to be about 1,200 acres. One deep test in the field failed to find any promising deeper sands. There are now 51 oil wells and two gas wells here and development is nearly complete. As of January 1, 1941, the field had produced a total of 1,573,400 barrels.

South Texas

12. L. B. Herring, consulting geologist, Corpus Christi, Texas
Developments in South Texas during 1940

This paper discusses the developments during the year 1940 in the South Texas area and suggests that the collapse of foreign markets caused pipe-line proration and local price cuts.

Twenty-eight new producing areas were found during the year. Drilling was slightly under the 1939 rate, and geological exploratory work was greatly reduced.

Four wildcat wells were completed in Wilcox sands, three producing gas and condensate and one producing oil with water. None of these discoveries appears to represent reserves of consequence.

Condensate production reached 8,800 barrels per day, and nine plants were operating on a repressuring or a recycling basis.

13. PHIL F. MARTYN and CHARLES H. SAMPLE, Houston Oil Co., Houston, Texas
Oligocene Stratigraphy of East White Point Field, San Patricio County, Texas

The East White Point oil field is located in south-central San Patricio County, Texas, on the Gulf Coastal Plain of South Texas, being situated approximately midway between Galveston and Brownsville, 20 miles inland from the Gulf of Mexico, and 5 miles northward across Nueces Bay from the city and deep-water port of Corpus Christi. Subsequent to the discovery of oil in the 5,600-foot sand by the Plymouth Oil Company in February, 1938, the field has been subjected to continuous development. As of January 1, 1941, approximately 240 oil and gas wells have been completed in the four productive sands between the depths of 4,000 feet and 5,900 feet, which wells have yielded approximately 5½ million barrels of oil.

Within the scope of this paper, the strata encountered in the drilling of the majority of the wells below a depth of 4,000 feet in the subsurface have been grouped in the Oligocene formation and the authors have restricted their study to the beds included in the interval below that depth and above the 5,600-foot (principal oil-producing) sand. Isopach and other geologic studies of the several sand and shale zones have presented some very interesting problems. The intermittent and periodic structure-making movements, and likewise the periods of quiescence, are reflected in the sedimentary intervals of the respective strata. The most outstanding feature of the stratigraphy, however, is the well developed erosional topography on the top of the 5,400-foot (Zone E) sand. Isopach maps of this stratum display the typical features of degradation and planation common to the erosion cycle of normal rivers in an area being subjected to cyclic rejuvenation. Similar maps of the overlying 5,300-foot (Zone D) shale reflect the effects of the deposition over the eroded topography. As suggested by the reconstructed terraces, and slopes attendant thereto, three periods of uplift and erosion are propounded. The erosional unconformity thus established, and advocated by the authors, offers additional criteria and evidence for the following: first, offlap or regression of the Gulf of Mexico at the close of Frio time, with the consequent development of stream drainage and erosional topography on the land surface; second, the location of an ancient Gulf of Mexico at some distance removed from the present location of the East White Point Field following the deposition of the 5,400-foot sand; and third, the delineation of the top of the Frio formation at the erosional break in the stratigraphy.

14. A. W. WEEKS, University of Texas, Austin, Texas
Late Cenozoic Deposits of Texas Coastal Plain between Brazos River and Rio Grande

This paper presents (1) a description of the deposits of the Coastal Plain between Brazos River and Rio Grande beginning with the Catahoula and extending upwards through the Recent, (2) a correlation of the up-dip terrace deposits with equivalent formations of the Gulf Coastal Plain, (3) a discussion of the age of these terrace deposits, (4) an outline of certain fault zones that are involved in the geologic history of the Coastal Plain deposits, and (5) a geologic history of sedimentation during late Cenozoic time.

The geologic section involved is as follows.

Recent	*Present Deposits, Sand Beach*
Pleistocene	Riverview First Street Beaumont or Sixth Street Lissie or Capitol Asylum Uvalde Bastrop Park Gay Hill Willis
Pliocene	Goliad Lagarto Lapara
Miocene	Fleming Cuero Oakville Catahoula

15. H. B. STENZEL, Bureau of Economic Geology, Austin, Texas
Sedimentary Cycles in Eocene of Texas Gulf Coastal Plain

A typical sedimentary cycle of the Gulf Coastal Eocene consists of cross-bedded sands, well bedded sands, silty brown shale, unctuous brown shale, glauconitic brown shale, massive glauconite marl, gray calcareous shale, impure limestone, gray calcareous shale, unctuous brown shale, silty brown shale, well bedded sands, and cross-bedded sands listed in ascending order. Cycles of this type are rarely complete, most of them are broken or interrupted by disconformities. Most of the disconformities occur either at the base of the cross-bedded sands at the beginning of the cycle (regressional hiatus) or at the base of the massive glauconite marl (transgressional hiatus). The positions of the disconformities in the stratigraphic section of eastern and central Texas are shown. The magnitude of the hiatuses is estimated with the aid of new methods.

WEST TEXAS

16. TAYLOR COLE, University Lands, Midland, Texas
ROBERT I. DICKEY, Forest Development Corporation, Midland, Texas
EDGAR KRAUS, Atlantic Refining Company, Carlsbad, New Mexico
Developments in West Texas and Southeastern New Mexico

Development in West Texas continued at about the same rate as during the previous two years, with 1,747 field wells being completed, and 119 wildcats. The percentage of wildcat strikes was unusually high in that 47 were producers while the percentage of dry holes was only 5.6%. Eighteen new discoveries (twice as many as during 1939) were recorded with fourteen from Permian rocks ranging from the Yates sand (upper Whitehorse) down to the upper portion of the Clear Fork. The four pre-Permian discoveries included one each from the Lower Pennsylvanian, Silurian, Simpson (Middle Ordovician), and Ellenburger (Lower Ordovician). Five of the new discoveries are in Crockett County. Many of the fields were extended considerably, and several geologically important wildcats were drilled.

The trend in exploration seems to be toward more and deeper wildcatting with probably a slow orderly development of the new discoveries except where near-expiration leases are held.

There have been very few improvements in drilling and production practices. Activity in geophysical exploration was at a high level in the central and southern portions of the Midland Basin and along the Eastern platform.

Development in southeastern New Mexico was less than the previous year with 542 wells being drilled. The percentage of dry holes (13.5%) ran higher than previously because of hazardous development in lenticular, irregularly cemented "sands" flanking the Artesia-Maljamar nose on the south and north. Few deep exploratory tests were drilled in spite of contiguous areas of West Texas being productive from pre-Permian formations. Only two new discoveries were recorded from southeastern New Mexico, but several fields were extended considerably.

17. W. T. SCHNEIDER, Honolulu Oil Corporation, Midland, Texas
Geology of Wasson Field, Gaines and Yoakum Counties, Texas

The Wasson field is near the central part of the Staked Plains or "Llano Estacado," in southern Yoakum and northwestern Gaines counties. At present it occupies a triangular-shaped area 15 miles long and 14 miles wide containing approximately 59,000 acres or 93 square miles. It is still in an active state of development and has been defined at only a few points by dry holes.

Geologically, the field lies on the extended axis of the Central Basin platform, but appears to be separated from it by a trough in northern Gaines County. For the purpose of this paper the structural-stratigraphic feature under discussion will be referred to as part of North Basin platform.

Two major axes, one trending N. 60° W., the other N. 30° E., combine with several minor parallel axes to form a compound structure. The combined effect of the structural elements gives the whole the appearance of a terraced platform which has been tilted to the northeast by post-Permian movement.

The problem of stratigraphy is typical of West Texas in that massive, porous dolomites with fewer clastics form the highs and grade basinward into thicker sections of interbedded dolomite and anhydrite containing more clastic materials.

The section penetrated by wells consists of: Recent, Tertiary, Cretaceous, Triassic, and Permian deposits. The reservoir is in porous dolomite 300 to 600 feet below the top of the San Andres. Detailed examination and recording of the well-cuttings show the body of the reservoir to have a reef-like cross section which may be accounted for by (1) chemical deposition on a marine high, or (2) reef-growth with attendant chemical deposition.

The combination of Permian structure and stratigraphy appears to have controlled the permeability, porosity, and the accumulation of fluids. Later folding modified the position of these fluids somewhat. For the field as a whole there is no direct relationship between the present structural elevation and the ability to produce oil.

The discovery well, Honolulu Oil Corporation and Davidson Drilling Company No. 1 Bennett, was drilled into oil on September 28, 1935. Development has been continuous since that time and 16,388,981 barrels of oil had been recovered from the field on September 1, 1940.

18. W. M. Osborn, consulting geologist, Midland, Texas
Stratigraphic Trap of Slaughter Field of West Texas

The Slaughter field of Cochran, Hockley, and Terry counties, Texas, covers approximately seventy squares miles and on February 1, 1941, it contained 162 producing oil wells.

Present control shows no structural closure. The field is situated on a series of noses dipping gently south-southeast but these do not control production.

The pay section, which is about 100 feet thick, is the Permian San Andres dolomite. The pay is a brown granular dolomite having inter-crystalline porosity. In some parts of the pay section larger openings also occur. The depth to the top of the pay, which is about 800 feet below the top of the San Andres, ranges from approximately 4,900 to 5,000 feet. The southern and eastern limits of the field are mainly determined by the structural position of this pay with reference to the water table.

Production to the west seems to be limited by contamination of the pay section with silt and anhydrite. Two structurally high dry holes on this side of the field showed large amounts of silt and anhydrite in the beds equivalent to the pay section.

The northern limits of production have not been defined but indications point to a breaking down of the section in this direction also.

19. W. A. Waldschmidt, Colorado School of Mines, Golden, Colorado
Progress Report on Microscopic Examination of Permian Crude Oils

Studies of several samples of Permian crude oil were made for the purpose of determining the source, character, and amount of the included organic residues. The method of obtaining the residues was similar to that used by Sanders. Diatoms, spines, plant remains, and fragments of other organic materials were observed in the residues examined, but further studies will be necessary before the source of these remains can be determined.

20. Taylor Cole, University Lands, Midland, Texas
Subsurface Study of Ellenburger Formation in West Texas

Various portions of the Ellenburger (Cambro-Ordovician) formation have been penetrated throughout the West Texas area bounded by Latitude 32° and 30° and Longitude 101° and 103°. The formation consists of fine to coarsely crystalline dolomites and dense limestones. These lithologic units are of no value even in local correlations when accurate work is desired.

A careful study has been made of the insoluble residues from most of the well cuttings available. The chief criterion for correlations is chert. Four main classes of chert are recognized: smooth, granular, chalky, and drusy. Each class may have several secondary characteristics, and gradational types are present. From this work the complete Ellenburger section, which is approximately 1,335 feet thick in western Crane County, has been divided into five zones. These zones when fitted into the section worked by geologists familiar with the Missouri section have approximately the following relationship.

Silt zone	Cotter
Smooth Chert zone	Jefferson City Roubidoux Gasconade

Upper Granular Chert zone
Chalky Chert zone.............. Eminence / Potosi
Lower Granular Chert zone

Chert zones have made it possible to locate accurately the stratigraphic position entered in the dolomite section. The upper part of the Ellenburger has been truncated in four wells in the Big Lake field (Reagan County). Restoration of the truncated part shows the axis of the folding to be parallel to the Permian folding (San Andres) which runs NW.-SE. rather than N.-S.

Some 275 feet of Ellenburger is absent from the base against the Apco Ridge (Pecos County), probably due to overlap, and about 900 feet has been eroded from the top of the section in this area.

21. ROBERT L. BATES, geologist, New Mexico Bureau of Mines and Mineral Resources, Socorro, New Mexico (Published with the permission of the Director)
Lateral Gradation in Seven Rivers Formation, Rocky Arroyo, Eddy County, New Mexico

The paper embodies results of a study of surface exposures of Rocky Arroyo, 12 miles northwest of Carlsbad, New Mexico. In the walls of this and adjacent canyons is revealed an abrupt lateral change in lithology in the Seven Rivers formation. A 275-foot section of gypsum with thin beds of dolomitic limestone merges into a thinner section of uniform dolomitic limestone with some sandstone beds. Evidence is presented to show that this change is the result of interfingering of gypsum and dolomitic limestone. Thin beds of the latter extend for some distance into the gypsum. However, thick layers of gypsum between beds of dolomitic limestone end abruptly and their places are taken by zones of red porous loosely crystalline calcitic limestone. These limestone beds become thinner away from the gypsum beds and finally pinch out, so that in the final analysis the gypsum beds are equivalent to bedding planes in the section of dolomitic limestone. Channeling of the canyon walls by present-day streams has produced a striking type of breccia, in which angular blocks of dense light-colored dolomitic limestones are firmly embedded in red crystalline highly calcitic limestone.

The following conclusions are suggested. The lateral change of section does not represent overlap, as has previously been suggested, but is an abrupt lateral gradation. This gradation is not a local phenomenon but occurs in the Seven Rivers formation for an undetermined distance at the same relative position back of the Capitan Reef, the controlling factor of Permian sedimentation in this region. Advance and retreat of the Seven Rivers seas is suggested, with the anhydrite-depositing environment approaching closest to the Capitan Reef in earliest Seven Rivers time and thereafter making shorter advances. The presence of the lateral gradation in the subsurface should be taken into account when correlating well logs penetrating the Seven Rivers section farther to the east.

22. L. R. LAUDON, University of Tulsa, Tulsa, Oklahoma
ARTHUR BOWSHER, University of Tulsa, Tulsa, Oklahoma
Mississippian Formations of Sacramento Mountains of New Mexico

Formations of Mississippian age are exposed along the west face of the Sacramento mountains of New Mexico from a short distance north of Alamogordo southward to the vicinity of Grapevine canyon. Detailed sections have been measured and the faunas collected throughout the entire area of exposure. The name Cabellero is proposed for the gray, nodular, marly limestone formation of Kinderhook age lying at the base of the Mississippian section. The Caballero formation has heretofore been considered as a part of the Lake Valley formation. The Lake Valley formation has been divided into three members, Alamogordo at the base, followed by Arcente, and capped by Dona Ana. The fauna of the Caballero formation is closely related to that of the Chouteau formation of the upper Mississippi valley region. The Lake Valley formation is entirely of early Osage age. Both Fern Glen and lower Burlington faunas can be recognized. Spectacular large bioherms characterize the Alamogordo member making it necessary to subdivide the member into several facies.

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23. L. C. SNIDER, president, A. A. P. G., Department of Geology, University of Texas, Austin, Texas
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24. W. T. Born, president, S. E. G., Geophysical Research Corporation, Tulsa, Oklahoma
Presidential address: *The Future of Geophysics*

25. Carey Croneis, president, S. E. P. M., Walker Museum of Paleontology, University of Chicago
Presidential address: *Micropaleontology, Past and Future*

This paper traces the rise of interest in microscopic fossils from the sixteen sixties when Leeuwenhoek's development of the forerunner of the microscope made their study possible, through the several centuries of their sporadic investigation in the interests of pure research by small groups of scientists, to the birth of the utilitarian science of micropaleontology a quarter century ago. The developmental phases of the science are then outlined, and the progressive multiplication of the micropaleontologic groups studied is considered.

The origin and growth of micropaleontology as a subject in university curricula is reviewed, and suggestions are made for the future expansion and improvement of training in this special field. In addition, consideration is given to the general academic background the prospective paleontologist should acquire in order best to serve his science as well as prove most valuable to the organization which purchases his services.

Finally the future of the science of micropaleontology is analyzed, and suggestions are made for the direction of efforts into new lines of investigation which may prove profitable in enlarging the scientific scope of the field and thus in enhancing its commercial significance.

Special Addresses

26. Robert E. Wilson, president, Pan-American Petroleum and Transport Company, and in charge of Petroleum Section, Raw Materials Division, Advisory Commission to the Council of National Defense
Petroleum and the War

27. J. Edgar Pew, vice-president, Sun Oil Company, Philadelphia, Pennsylvania
The Fifth Dimension in the Oil Industry

28. N. C. McGowen, president, United Gas Pipe Line Company and Union Producing Company, Shreveport, Louisiana
Natural Gas with Regard to Its Place in National Defense

29. Sumner T. Pike, commissioner, Securities and Exchange Commission, Washington, D. C.
The Petroleum Geologists and the S.E.C.

Papers of General Interest

30. Edgar W. Owen, secretary-treasurer, A. A. P. G., with Lew H. Wentz, San Antonio, Texas
Rôle of Surface Geology in Petroleum Exploration

Although the use of surface geology as an independent method in petroleum exploration has become practically obsolete, it should be employed to a much greater extent in conjunction with geophysical, subsurface and other modern techniques. Where familiar methods of mapping surface structure are not applicable, much valuable information can be obtained at low cost by physiographic studies. The application of surface, structural, and physiographic work to exploration problems in the Gulf Coastal Plain and in the Permian Basin is discussed. Certain types of physiographic anomalies of diagnostic value are described, and some of the difficulties surrounding their interpretation are indicated.

31. L. W. Storm, Schlumberger Well Surveying Corporation, Corpus Christi, Texas
Résumé on Sedimentation in Gulf Coast Region of Texas and Louisiana

The structure, composition, and manner of accumulation of present-day deposits along the coast are described along with those of Recent and Pleistocene time still largely intact. Meaning of the topography on the surface of these deposits, and their relation to Glacial history are discussed.

Following this and using it as a background, the more significant features of formations back to the beginning of the Eocene are reviewed.

Topics receiving special attention are: delta structure of several kinds and the con-

cept of a Deltaic Coastal Plain; subsidence under load and the Gulf Coast geosyncline changes of Gulf Coast sediments in the direction of the dip and along the strike; and structural changes contemporaneous with deposition of sediments.

The manner in which the facts and theories discussed may be used by geologists in the search for oil.

32. H. D. WILDE, Humble Oil and Refining Company, Houston, Texas
Why Crudes Differ in Value

Although crudes are all fundamentally made up of mixtures of hydrocarbons and are hence similar in this respect, the type of hydrocarbons and the relative proportions in which they are present can vary widely from crude to crude. This variation causes crudes to differ in value. This value is established by the refineries who use crudes as a raw material for the manufacture of the various finished products. Some crudes are in demand and are assigned a high value because substantial yields of good quality products can be made from them with little special processing, whereas, others are penalized because certain products are not present or are of such poor quality that special processing (which is usually expensive) is necessary to make these products saleable. In order to evaluate crude, a sample is assayed in the laboratory, whereby the yield and quality of the primary products are determined and these data are used in computing the value of the crude. Other factors, such as transportation costs to refinery centers and the ultimate consumers and competitive conditions, are also considered in arriving at the price paid for a crude at the well.

33. BASIL B. ZAVOICO, Chase National Bank, New York City
Foreign Developments during 1939 and 1940

The oil industry has inevitably been affected by the present Great War, since it supplies the prime movers for striking power in the conflict. A unique feature of the business is that unlike other war supplying industries its rapid growth usually precedes major conflicts; and exploration and construction stagnate while they last. Time necessary for exploration and development of new resources and for construction of large new refining plants—together with heavy demand for metals at the time when these products are vitally needed elsewhere—all tend to slow down active development of new crude oil reserves during actual hostilities. In the present war and immediately preceding it the increased range of bombing planes, as well as the political uncertainties in large portions of the world, further served to reduce new work in the oil industry to a minimum except in the Western Hemisphere. However, even here in portions of South and Central Americas the social and political changes under way brought exploration for new reserves to a virtual standstill. Geologists and geophysicists were unavoidably affected in the foreign fields, resulting in a sharp increase in the domestic supplies in these two professional classifications.

A revolutionary effect of the war is the growing volume of synthetic hydrocarbons reaching the markets under the vital necessities of the Axis powers and to a lesser degree of Soviet Russia. Improved processes and quantity production will result in lowering costs and some synthetic hydrocarbons may prove to be competitive with corresponding crude oil derivatives within a rather narrow span of years, particularly in cases where long distances separate sources of supply from markets. The indicated developments may have a very considerable economic effect on the various phases of the oil industry.

Among principal producing countries of the world, outside of the U. S. A., none increased its production except Colombia where completion of a new pipe line allowed somewhat larger exports, production of this country increasing from 23,774,151 barrels in 1939 to 25,526,492 barrels during 1940, with the result that in 1940 production of the world, outside of the United States, declined to about 790,000,000 barrels (2,158,469 barrels per day) from 810,000,000 barrels (2,219,178 barrels per day) produced in the preceding year. More particularly dormant was the exploration work without any new really major regional or local discoveries. Such trend is likely to continue for the duration of the war and only the end of the conflict should bring the renaissance in all exploratory activities with a subsequent rapid expansion in the demand for qualified technicians.

34. P. E. FITZGERALD, Dowell, Incorporated, Tulsa, Oklahoma
F. R. JAMES, The Dow Chemical Company, Midland, Michigan
RAY L. AUSTIN, Dowell, Incorporated, Casper, Wyoming
Laboratory and Field Observations of Effect of Acidizing Oil Reservoirs Composed of Sands

The widespread use of chemicals on oil and gas reservoirs composed of limestones has attracted the attention of engineers and geologists to the many wells producing from sands. The early attempts to treat wells producing from sands were not uniformly successful. During the past several years the authors have been collecting cores from various producing horizons; most of them have been studied in the laboratory. In certain areas chemicals have been used on sands with good results. This paper discusses the results of the laboratory work and contains a compilation of well treating data. Of the more than 300 cores studied, over 80% showed an increase in permeability when acidized in the laboratory. The average permeability increase was over 500%. The average acid solubilities of the more than 80 different oil-producing sands was 8.5%.

The authors have also included data on compressive strength of the cores before and after acidizing and chemical and x-ray analyses of typical sands.

35. William L. Russell, Wells Surveys, Inc., Tulsa, Oklahoma
Applications of Radioactivity Logging

Radioactivity logging is the only known method of making accurate lithologic records through casing and cement. At present, radioactivity logs are used chiefly to determine exactly where to perforate the casing and cement, and the process has been highly successful in this use. Other applications consist in determining sample lag, making correlations and cross sections, locating faults, mapping subsurface structure for deeper drilling, logging beds too thin for electric logs to record, making detailed lithologic records of oil sands for use in connection with the recovery of oil by water flooding, and surveying potash deposits in cased wells. Well Surveys, Inc., has also developed a method for determining the radioactivity of cores and samples which has proved its value in interpreting the logs and in solving problems of sedimentation.

36. F. H. Lahee, Sun Oil Company, Dallas, Texas
Wildcat Drilling in 1940

Statistics on wildcat drilling during 1940 indicate that approximately 12.8% of the holes drilled, and 13.5% of the footage drilled, was successful in discovering oil or gas. The average depth of hole was over 3,640 feet, or more than 300 feet greater than in 1939.

Figures on the relative success of the various technical and non-technical methods of selecting wildcat locations are presented.

37. J. C. Barcklow, Lane-Wells Company, Oklahoma City, Oklahoma
Radioactivity Well Logs, Their Use and Application in Fields of Petroleum Geology, Economic Geology, and Petroleum Engineering

Much experimental work has been done in the past on radioactivity as applied to making well logs. Recently, about June, 1940, such logs were offered to the industry on a commercial basis. Since that time great strides have been made in the technique of producing these logs. With the advent of logs of this sort many uses and applications for them have suggested themselves. They no doubt will occupy a prominent place in the petroleum industry as the members of that industry become better acquainted with them.

Rocky Mountains

38. C. E. Dobbin, U. S. Geological Survey, Denver, Colorado
Developments in Rocky Mountain Region in 1940

There were no major discoveries of oil and gas in unproved areas in the Rocky Mountain district in 1940, most of the drilling being restricted to inside locations in major fields.

In Wyoming, good shows of oil encountered in the Shannon sandstone member of the Steele shale (Upper Cretaceous) in the Cole Creek field during deeper drilling in 1937 were tested further in 1940 and commercial production found; one relatively small oil well was drilled in the North Labarge field, Sublette County, about two miles northwest of the nearest production in the Labarge field; and wells deepened a few feet in the Tensleep sandstone (Pennsylvanian) in the Mahoney field, Carbon County, and to the basal member of the Tensleep in the Lost Soldier field, Sweetwater County, were good oil wells. During 1940, commercial amounts of oil were first found in the Tensleep in the East Mahoney (West Ferris) field, Carbon County. No new producing zones were found elsewhere in the Rocky Mountain district during 1940. However, in February,

1941, commercial amounts of oil were first found in the Sundance formation (Upper Jurassic) in the Wilson Creek field, Rio Blanco County, Colorado.

In Wyoming the Frannie field, Park County, was extended almost one-half mile northwestward into Carbon County, Montana; Sundance production was extended eastward and southeastward about one location in the Lance Creek oil field, Niobrara County; the Labarge oil field was extended westward by relatively active drilling; and Tensleep sandstone production was extended about ¼ mile northeast in the Wertz oil field, Carbon County. Gas production in the Frontier sandstone (Upper Cretaceous) was extended about ½ mile northwestward in the Muskrat field, Fremont County, and less than ½ mile southeastward in the near-by Big Sand Draw field. In the Hiawatha field, Sweetwater County, commercial gas was found in the Wasatch formation (Eocene) about a mile north of the nearest producer.

In Colorado, a good Morrison (Upper Jurassic) sand well was found in the Wilson Creek oil field, Rio Blanco County, ¾ mile southwest of the nearest producer; and on the east side of the Hiawatha oil and gas field, Moffat County, one relatively large oil well and one relatively small one were found in sandstones of the Wasatch formation.

During the year, very few important wildcat wells were drilled in the district. In Montana, a 7,116-foot dry hole was drilled through the Sundance sand on the Absarokee structure, Stillwater County. In Wyoming, a 6,302-foot dry hole was drilled to Pennsylvanian beds in the Middle Baxter Basin area, being the first well to test certain lower zones in the Baxter Basin fields; a 4,243-foot dry hole was completed in the Deadwood formation (Cambrian) on the Bull Creek structure, Crook County; and an 8,343-foot dry hole was completed in the Tensleep sandstone on North Geary dome, Natrona County.

A new depth record for drilling in Wyoming was established at 10,121 feet in the Badger Basin field, Park County.

Several relatively short pipe lines were built in the district during 1940, one of the larger ones being the 100-mile line between the Billy Creek gas field, Johnson County, Wyoming, and the Big Sand Draw gas line at Casper.

39. Harry Oborne, consulting geologist, Colorado Springs, Colorado
Paleozoic Correlations from Southern Rocky Mountain Front Range to Oklahoma-Texas Panhandles

By means of measured sections and well logs tentative correlations are made from Colorado Springs to the Amarillo Arch. While these correlations are not absolute they are presented in the hope that they may be of use to geologists working in the areas or with the formations involved. The "crinkly limestones" of the Front Range are believed to represent a zone, rather than definite beds which may be followed continuously. This zone is believed to correlate, at least in part, with the Blaine gypsum, and San Andres and Kaibab limestones. The Lyons sandstone, the age of which has been a serious problem because of lack of fossils, is provisionally correlated with the Glorietta of New Mexico and the Duncan sandstone of the Panhandles. By means of well logs and cuttings the Stone Corrall anhydrite and dolomite is carried from the Texas Panhandle into Baca and Las Animas counties in Colorado. Its probable equivalent is shown in well logs to extend into the area between Pueblo and Colorado Springs, where its identity is lost in the upper part of the Fountain arkose. According to this interpretation the Fountain formation would range in age from Cherokee, or perhaps even pre-Pottsville, to Permian. Evidence presented tends to indicate that the Amarillo Mountains may have been uplifted beginning in early Pennsylvanian time and continuing until late Pennsylvania time and that the Marmaton was a period during which great sheets of arkose were deposited in widely scattered areas in central Kansas, along the ancestral Rocky Mountains in Colorado and northeastern New Mexico, and along the flanks of the Amarillo Mountains in the Texas and Oklahoma Panhandles, their distribution being controlled by streams rather than offshore currents. The arkoses of the Oklahoma Panhandle may be the attenuate edges of the arkose sheets of the Texas Panhandle or they may have had a more proximate source.

40. W. A. Waldschmidt, Colorado School of Mines, Golden, Colorado
Results of Petrographic Studies of Sandstone Cores from Rocky Mountain Structures

Detailed petrographic studies of sandstone cores from productive and non-productive structures in the Rocky Mountain region were made to determine not only the

physical characteristics of the sandstones but also the nature and distribution of the cementing materials. The sandstones have been divided into two general groups on the basis of the cementing or binding materials: first, those in which the grains are bound together by clay products; and second, those in which crystalline minerals form the cementing material. In the first group effects of compaction were noted. In the second group, sequence of deposition of cementing minerals was observed. The deposition of quartz, dolomite, and anhydrite in the order given is common in some sandstones. In others, quartz and calcite are the only cementing minerals, and of these calcite is the last mineral deposited. Other combinations of these four minerals were observed. Furthermore, sequence of deposition of the same minerals has been established tentatively for the geologic section from the Bell sandstone upward through the Mesaverde sandstone.

Also presented are some probable effects of crystalline cementing materials upon migration and accumulation of oil and gas, upon acid treatment of wells, and upon pressures existing in oil and gas fields.

41. W. C. Toepelman, University of Colorado, Boulder, Colorado
Microfaunas of Niobara and Benton in Foothills of Northern Colorado

This paper is a preliminary report on the first of a series of studies which will attempt to establish recognizable foraminiferal zones in the Cretaceous sequence of eastern Colorado. Because previous reports on the Niobrara and Benton horizons of Nebraska, Kansas, and Wyoming have shown abundant faunas, these horizons in the foothills of the Front Range of northern Colorado were chosen as the most promising for this investigation. Progress thus far reveals a fauna of upwards of thirty species from the Niobrara. Indications are that this fauna is most prolific in the lower 300 to 400 feet of the formation and that this zone should be rather easily recognizable in well cuttings. The upper member of the Benton, which is a sandstone of variable thickness, seems to be entirely barren of fossils. About 125 to 200 feet below this is a zone of limy shale which yields a fair fauna of Foraminifera. This fauna is apparently very similar to, but less abundant than, that of the overlying Niobrara, and can not be readily separated from the latter in northern Colorado.

It is planned to extend this study of the Benton and Niobrara south to beyond Trinidad, Colorado, and also eastward along the Arkansas River to the Kansas boundary. Scattered samples from Benton outcrops north and east of Trinidad indicate a more abundant fauna of Benton age will be found; also that the barren zone of the top of that formation in northern Colorado is not present to the south.

South Mid-Continent

42. H. F. Smiley, for committee of North Texas Geological Society, Witchita Falls, Texas
New Developments in North and West Central Texas, 1940

The most important development in the North and West-Central Texas area during the year was the remarkable number of new producing horizons discovered. In the K. M. A. field the Ellenburger (Ordovician) was found productive in the western part; two pools on the Bend arch in Young County and one pool on the eastern edge of the Permian Basin in Stonewall County found production in the Chappel limestone (Mississippian); in the Fort Worth syncline, a pool in Clay County and another in Montague County found production in the lower Bend conglomerate; the Caddo (Bend) was found productive in two pools on the Bend arch in Archer County, in two pools in the Fort Worth syncline in Clay County, and in one pool in Montague County; the Strawn series (Pennsylvanian) yielded production in two pools on the Bend Arch in Archer County and in one pool on the east flank of the arch in Clay County; the Canyon series yielded production in two pools on the west flank of the Bend arch in Baylor County, in one pool in Jones County, in one pool in Foard County on the Electra arch, and in one pool in Wilbarger County in the Red River syncline. New production was also found in the Cisco series in practically every producing county in the area, the most significant of which was probably in the Fargo pool in the Red River syncline in Wilbarger County.

Probably the only new stratigraphic discovery in the area was the tentative identification of Viola limestone (Ordovician) in two of the deeper wells in Clay County and two in Montague County and one in Wise County, all in the Fort Worth syncline.

Total production for North and West-Central Texas for 1940 was 49,221,213 barrels.

43. W. J. Hilseweck, Gulf Oil Corporation, Fort Worth, Texas
Walnut Bend Pool of Cooke County, Texas

The Walnut Bend pool is the first major deep discovery in the Marietta-Sherman syncline, a northwest-southeast trending feature which extends from southwestern Carter County, Oklahoma, to southeastern Grayson County, Texas, parallel to the Criner Hills axis and the Muenster Arch. In this pool 1,000 feet of Comanche rocks overlie the 4,200 feet of Upper and Middle Pennsylvanian (Canyon and Strawn) sediments, and beds of lower Simpson (Oil Creek) age underlie the Pennsylvanian rocks. Pre-Pennsylvanian rocks show the Walnut Bend structure as an elongate anticline. This structure was formed on an arch folded in early Pennsylvanian (pre-Bostwick) time and the Marietta-Sherman syncline was formed in late Deese time by the downwarping of the middle part of this arch. Over one and one-half million barrels of oil have been produced from 6 sandstone zones between the depths of 4,100 and 5,100 feet, and from 2 dolomite beds in the Simpson group. Occurrence of oil in the sandstone zones at 4,900 and 5,100 feet is controlled by anticlinal structure over the closely folded Ordovician beds, Electrical log cross sections are presented to indicate that oil in the 4,100-, 4,600- and 4,700-foot zones occurs in a stratigraphic trap formed by gradation of standstone into shale.

44. H. N. Fisk, Louisiana State University, University, Louisiana
Midway-Wilcox Deltaic Mass

The lithologic unit previously considered to be of Sabine (Wilcox) age in the Sabine uplift area of Louisiana is divisible on the outcrop into conformable beds carrying Wilcox fossils and upper Midway fossils. The Midway fauna occurs throughout several hundred feet of section above the typical Midway shale reflection on electrical logs. Isopach maps and cross sections developed from electrical logs and paleontological reports of deep test wells from east Texas to southern Alabama show that during the time of deposition of the marine Midway and Wilcox of Texas and Alabama, a great deltaic mass, reaching a thickness in excess of 3,000 feet, was accumulating in the Mississippi Embayment of eastern Louisiana and central Mississippi. The presence of interpretable fossil assemblages appearing in beds which interfinger with the deltaic mass along its northwestern margin is important in determining the age of the mass and in field mapping in the Sabine uplift area.

45. J. O. Barry, Louisiana Geological Survey, University, Louisiana
Correlation of Wilcox Faunal Units of Louisiana

The discovery of forty new fossil localities permits a better definition of the three faunal units of the Louisiana Sabine (Wilcox): the Sabinetown (youngest), Pendleton, and Marthaville beds (oldest). Fossils were collected from three Sabinetown outcrops, twenty localities of Pendleton age, and from seventeen localities which carried a Marthaville fauna. The study of these fossils substantiates the long-standing correlation of the Louisiana section with the marine Wilcox of Alabama. The presence of *Ostrea multilirata* Conrad, a guide fossil of the basal Wilcox Seguin formation of Texas, associated with *Ostrea thirsae* (Gabb) in the Marthaville beds is of importance because it establishes a connecting link between the basal Wilcox faunas of Alabama and Texas.

46. R. J. Le Blanc, Louisiana Geological Survey, University, Louisiana
Correlation of Upper Midway Fauna of Louisiana

The lower Eocene sediments below the basal Sabine (Wilcox) *Ostrea thirsae* zone have a surface thickness of approximately 800 feet in the Sabine Uplift region of northwestern Louisiana. The upper 300 feet of the sediments contain a very limited fauna. The lower 500 feet of sediments carry a varied fauna which is older than the Solomon Creek fauna of Texas (basal Wilcox or upper Midway in age) and correlated with the upper Midway faunas of the Alabama Naheola formation and the Kerens member of of the Wills Point formation of Texas. This correlation is based on the results of a detail study of over ninety species from fifteen previously undescribed localities in Sabine, Natchitoches, and DeSoto parishes.

47. Grover Murray, Jr., Louisiana Geological Survey, University, Louisiana
Midway Stratigraphy of Sabine Uplift

The Midway sediments which cropout in northwestern Louisiana outline the highest structural portion of the Sabine uplift. They are divisible on the surface into three formations, the Naborton (oldest), the Logansport, and the Hall Summit (young-

est). Each formation is a lithologic unit which consists of a basal sand member, a middle lignitic shale member, and an upper calcareous member. The surface lithologic units can be traced locally into the subsurface by use of driller's logs and electrical logs. The practicability of employing these units for mapping is shown by the fact that detailed mapping of formations delimits the various oil fields of this area and shows the highest structural portion of the Sabine uplift to be in the DeSoto-Red River field.

Central and Eastern States

48. Alfred H. Bell, Illinois Geological Survey, Urbana, Illinois
Oil and Gas Development in Eastern Interior Basin in 1940

Oil production in the Eastern Interior basin reached a new high in 1940, about 54 per cent above 1939. Most of this increase was due to the drilling of wells in the Devonian limestone in the Salem and Centralia pools, Illinois. Thirty new oil pools were discovered in Illinois, and several in southwestern Indiana and western Kentucky. The Indiana discoveries were within about 10 miles of the Wabash River which is the Illinois-Indiana state boundary in this area. Twelve of the 30 new pools discovered in Illinois are in counties bordering the Wabash River. Geological conditions revealed by the new drilling are discussed.

49. Paul H. Price, State geologist, West Virginia Geological Survey, Morgantown, West Virginia
A. J. W. Headlee, chemist, West Virginia Geological Survey, Morgantown, West Virginia
Geochemistry of Natural Gas in Appalachian Province

This paper contains the results of further studies on the variations in the composition and properties of natural gas by geologic and geographic distribution.

New data corroborate the composite regional variations previously published. The regional map has been extended to include the gas and oil fields in Canada which lie in the Appalachian Province north of Lake Erie.

Well to well variations in the composition of the gas in several individual reservoirs are given. Definite relationships exist between the composition of natural gas and associated oil both areal and quantitative.

Numerous samples of near-surface gases and gases from coal seems have been analyzed.

A résumé of the geologic occurrence of methane, ethane and higher boiling saturated compounds, nitrogen, carbon dioxide, and hydrogen sulphide is given. Also the relationship of these gases to their associated constituents, i.e., sand, shale, limestone, coal, water, brine, calcium sulphate, are discussed.

The origin, migration, and natural storage of gas and oil are discussed in the light of these data.

50. E. T. Heck, West Virginia Geological Survey, Morgantown, West Virginia
Gay-Spencer-Richardson Oil and Gas Trend in West Virginia

An outstanding example of the control of oil and gas production by sand distribution is provided by the Berea sand trend extending from Gay in Jackson County, northeastward through Spencer, Roane County, and Richardson, Calhoun County. With the exception of a few undeveloped edge areas, the producing area closely follows the extent of the sand. The producing area varies in width from less than one mile to about three miles. Cross sections show that the sand pinches out in both directions at right angles to the trend and the linear shape strongly suggests a buried beach. Although only the southwestern part of the trend is considered in the paper, the trend is known to continue northeastward to Fink Creek, Lewis County. A total length of over 55 miles.

Within the sand body the adjustment of oil and gas to structure is very good, with oil in the synclines and gas on the intervening anticlines. No areas containing only water in the Berea sand are known along the trend.

Secondary recovery of oil by means of gas drive is being tried near Spencer, on an experimental basis, with encouraging results.

51. Max W. Ball, consulting geologist, Edmonton, Alberta, Canada
T. J. Weaver, American Production Company, Grand Rapids, Michigan
Douglas S. Ball, student, Colorado School of Mines, Golden, Colorado
Shoestring Sand Gas Fields of Michigan

The "Michigan Stray" sand, from which most of Michigan's gas is produced, consists of a series of sand bars formed on off-shore shoals in a shallow Mississippian sea. The shoals that caught the bars are on long, anticlinal trends, the sea-floor topography being determined partly by structure and partly by erosion during a previous period of emergence. In some fields enough data are available to show the size and shape, and configuration of the bars, and in at least one the sea-floor topography has been worked out, and the cause and manner of deposition of the bar are plain. The main bar formed against a small sub-sea hill, the top of which may have protruded as an island, and a smaller bar formed on a lower shoal on the opposite side of a cross channel through which enough current passed to keep the channel almost, but not quite, free of sand.

The sand bodies are of some magnitude. The largest so far explored is about 8 miles long and 3 wide and held about 50 billion cubic feet of gas. Here three parallel bars were formed and eventually coalesced into a single great bar, featured by three main undulating ridges with intervening hollows. The upper surface of the sand body is strikingly similar to the topography of a present-day sand-bar area.

None of the Kansas and Oklahoma shoestring sands described by Bass and others shows sand-bar characteristics and origin more clearly than these Mississippian sand bars of Michigan.

52. L. E. Workman, State Geological Survey, Urbana, Illinois
I. T. Sehwade, State Geological Survey, Urbana, Illinois
Subsurface Strata between Base of Osage Group and Top of Devonian Limestone in Illinois

The lithology of the formations between the base of the Osage group and the top of the Devonian limestone in Illinois, as revealed by subsurface studies, is described. A series of isopach maps and cross sections shows the lateral variations in thicknesses of the entire group of sediments and also of the upper Kinderhook, Rockford, and New Albany divisions.

53. Joseph Purzer, Phillips Petroleum Company, Shreveport, Louisiana
Warren B. Weeks, Phillips Petroleum Company, Shreveport, Louisiana
Development in Southern Arkansas and Northern Louisiana during 1940

Annual oil production for this area during 1940 increased by 3,563,675 barrels, or 7.6 per cent over the figure of the previous year. South Arkansas produced 25,790,380 barrels and North Louisiana 24,381,760 barrels, for a total of 50,172,140 barrels.

Of the 169 wells drilled in Southern Arkansas, 38 were dry; while 131 of the 651 North Louisiana wells were dry. The majority of the wells drilled in South Arkansas were drilled to the Smackover formation, with the Hosston ("Travis Peak") formation a close second. In northern Louisiana a great majority of the wells ended in the Gulf series, while the majority of the remaining wells ended in the Eocene series. The preponderance of Gulf wells in north Louisiana is due largely to drilling in the old Caddo field. Prospecting and development in southern Arkansas continued to point to the Smackover formation, while in northern Louisiana the search for Wilcox production predominated.

South Arkansas had one new gas-distillate field from the Smackover limestone, a new oil field from the Paluxy formation, and one producing from the Hosston formation. North Louisiana had two new oil fields and two new gas fields in the Wilcox formation, and one gas field in the Paluxy. A new field from the Hosston was in prospect at the end of the year.

54. Leo Hendricks, Bureau of Economic Geology, Austin, Texas
Correlation of Subsurface Sections with Outcrops of Ellenburger Formation of Texas

Wells that have penetrated to the Cambrian in North-Central Texas reveal a series of limestones and dolomites of varying thickness, which has been identified by lithologic evidence as belonging to the Ellenburger formation. Based on the variation in types of contained cherts as shown by a study of insoluble residues from cuttings, the thickest development of the formation in the subsurface can be subdivided into four units. By similar study of insoluble residues of samples from carefully measured sections on the outcrop of the Ellenburger in the Central Mineral region of Texas, it is possible to recognize the subsurface units at the surface. The age of the measured sections can be determined by faunal correlation. The age correlation carried into the subsurface of North-Central Texas by means of the insoluble-residue units indicates that the ap-

parent variation in thickness of the lower part of the Ellenburger is due to lateral change in lithology. Limestones underlying the Ellenburger as defined at the surface grade laterally in the subsurface into dolomites identical in character with those of Ellenburger age. Hence a portion of the so-called Ellenburger in the subsurface of North-Central Texas is pre-Ellenburger in age.

55. James L. Carlton, University of Chicago, Chicago, Illinois

Geology of Bartelso Oil Field, Clinton County, Illinois

The paper gives the location, stratigraphy, structure, production, and oil and water analyses of this field. Subsurface contour maps on the top of the Herrin (No. 6) coal, the base of the Golconda limestone, and on the top of the Devonian producing horizon show two small domes. Analysis was made of an oil and water sample from the field and statistics are given. The Cypress producing graph seems to show the production from that horizon to be declining while that from the Devonian is too recent for any definite estimate.

56. Park J. Jones, The Texas Company, Fort Worth, Texas

Introduction to Technique for Estimating Oil Reserves

The volume of oil ultimately recoverable from reservoirs is a function of a number of variables, the more pertinent of which may be listed as follows: (1) types of porous media, (2) sources of pressure, (3) reservoir volume factors, (4) connate water contents, (5) porosities and pay thicknesses, (6) permeabilities and permeability distributions, (7) selective location and selective completion of wells, (8) rates of recovery, (9) total or partial pressure maintenances, (10) secondary recovery methods, (11) crude prices and (12) economic limits. The volume of oil ultimately recoverable from individual properties is also a function of the listed variables but in addition it depends on migration of oil away from or into the said properties.

A method of estimating oil reserves from 19 different combinations of porous media and chief sources of pressure is presented in terms of pay thickness, porosity, connate water, reservoir-volume factors, permeability ratios, and operating methods relative to current oil prices and economic limits.

An outline of the method is included as a part of a paper entitled "Introduction to Optimum Spacing of Oil Wells" which was presented before the American Petroleum Institute, Southwestern District, Division of Production, February 27 or 28, at Shreveport, La.

57. R. P. Grant, geologist, Lansing, Michigan

Oil and Gas Developments in Michigan in 1940

The southwestern part of Michigan was the center of oil and gas activity for the state during the greater part of 1940 with activity increasing in the "Basin" area as the year closed.

The discovery and partial development of two new shallow "Stray" sand (Mississippian) gas areas and important extensions elsewhere have increased materially the gas reserves of the state. Gas production during 1940 was approximately 40 per cent greater than in the previous year.

Dispite numerous oil discoveries and extensions to proved areas, the additions to known oil reserves were of no great consequence. Oil production for 1940 was actually sixteen per cent less than in 1939 but a general strengthening in price partly offset this decline.

Several geophysical parties were reported operating in the Southern Peninsula but core testing seemed to be the favored exploratory method.

The search for new deep producing zones has received some encouragement. In the "Basin" substantial gas showings were encountered in the basal Salina (Silurian). In southwestern Michigan showings of oil were reported at the approximate horizon of the St. Peter sandstone.

58. Kendall E. Born, State Division of Geology, Nashville, Tennessee

Oil and Gas Possibilities in Northern Cumberland Plateau

(Published with the permission of the State geologist)

The northern Cumberland Plateau is surfaced with sandstones, shales, and coals of Pennsylvanian age which aggregate over 3,000 feet in thickness. The Coal Measures are underlain by 900–1,000 feet of Mississippian rocks which, in turn, rest upon as much as 200 feet of Silurian beds that thin out rapidly to the west where the Chattanooga shale is underlain by Ordovician strata.

Structurally, the northern Cumberland Plateau is a monocline dipping gently to the east toward the highly folded and faulted Appalachian structural province. The Plateau is bordered to the northeast by the Pine Mountain thrust block and to the east and southeast by the Cumberland Mountain-Walden Ridge fault system. Strong secondary faults are present in southern Morgan County. Within the Plateau proper gentle dips prevail.

The upper and middle Mississippian strata have been productive in the Oneida and Glenmary areas in Scott County, respectively, and the Fort Payne of lower Mississippian age is the producing formation in the Boone Camp pool in northern Morgan County.

The subsurface stratigraphy and general structural conditions of the area are discussed and special emphasis is placed upon the pre-Mississippian possibilities.

59. J. R. Lockett, president, Appalachian Geological Society and Committee
Developments in Appalachian Area during 1940

60. F. R. Denton and R. M. Trowbridge, consulting geologists, Tyler, Texas
Developments in East Texas during 1940

Three oil fields were discovered and oil production found in a gas field in East Texas during 1940.

The Hawkins field of Wood County which is producing from the Woodbine is a discovery of major importance and has set in motion a large-scale leasing and geophysical program.

Routine development of proved oil fields kept completions at approximately the 1939 level. Relatively few exploratory tests were drilled.

North Mid-Continent

61. Edward A. Koester, Darby Petroleum Corporation, Wichita, Kansas
Developments in North Mid-Continent in 1940

Kansas experienced a year of increased activity both in development and wildcatting, but results in the latter were relatively less fruitful. The number of total completions increased 33.9 per cent over 1939 and the dry hole percentage dropped from 24.7 per cent to 20.3 per cent. Initial oil production per well fell slightly from 1,577 barrels to 1,561 barrels, but the completion of 1,421 oil wells developed about 2,200,000 barrels of new potential compared to 1,500,000 barrels of new potential in 1939. Despite less activity in the Forest City basin, wildcatting increased from 95 completions in 1939 to 145 in 1940, but no important pools have yet been developed among the 23 discoveries. The most promising, as well as the most important of these pools, is the Ray pool in Phillips County, which previously had had but one small pool. In the Forest City basin, an oil and gas discovery of doubtful value was made in the McLouth pool of Jefferson County. The Bemis-Shutts, Burnett, Bornholdt, Trapp, Hall-Gurney, and Zenith pools account for 42 per cent of the new wells and 61 per cent of the new potential. Numerous extensions to old pools were made and many pools were joined.

In Nebraska the Falls City pool of Richardson County was the scene of the completion of 25 oil wells and seven dry holes. This pool produces low-gravity oil from a dolomite in the upper portion of the Devonian that is generally referred to as "Hunton." The wells respond favorably to acid treatment but water encroachment is rapid and it is doubtful that "Hunton" production in this pool will ever be of much importance. Thirty wildcat dry holes and one small oil well were completed elsewhere in Nebraska in 1940.

The Forest City basin play in Missouri resulted in the completion of seven additional deep failures and northeastern Missouri drew seven dry holes. There was also some moderately successful shallow gas development in the area east of Kansas City. There was a little intermittent drilling in Iowa, and some in the Dakotas, but the latter states were the scene of much checkerboard leasing and exploratory work.

62. Luther E. Kennedy, chairman of committee of Tulsa Geological Society, Tulsa, Oklahoma
Occurrence of Oil and Gas in Pennsylvanian Sands in North Central and Northeastern Oklahoma and Southeastern Kansas

The oil and gas development maps of the northern Mid-Continent show the vast number of producing wells and fields in north-central and northeastern Oklahoma and in southeastern Kansas. These are generally described as being old Pennsylvanian pools about which geologists in general know few of the details. This paper is a joint effort of a number of geologists to divide this production into different stratigraphic horizons.

A series of four maps show where oil and gas are produced from sands in the Pennsylvanian below the base of the Cherokee, in the Cherokee formation itself, in the interval between the top of the Cherokee and the Checkerboard limestone, and in the interval from the Checkerboard limestone to the top of the Pennsylvanian. Cross sections show the position of these sands and units in the stratigraphic column. It is hoped that these maps will furnish additional information on the character and position of these sand bodies, and on the occurrence of oil and gas in them.

63. EDWIN A. DAWSON, chairman of committee of Shawnee Geological Society, Shawnee, Oklahoma
Occurrence of Oil and Gas in Pennsylvanian Sands in Central Oklahoma

64. J. A. MULL, Republic Natural Gas Company, Wichita, Kansas
Stream Channels Applied to Arbuckle of Central Kansas Uplift

The Arbuckle surface on the nucleus of the often rejuvenated northwest-southeast-trending Central Kansas uplift was exposed as a land mass at intervals before the first Pennsylvanian sea invasion, for sufficient time to permit the positive and negative features of topography to be well developed. Subsequent movements have not greatly altered the detail topography on this nucleus. As a consequence, dendritic and radial drainage patterns can be traced by well control throughout the area. These channels are largely responsible for the separation of most of the buried hills which are now productive of oil. Outside the nucleus of the uplift, the above principles still apply, although they play a minor role in some areas as a result of early Pennsylvanian movement.

CALIFORNIA

65. EUGENE H. VALLAT, Continental Oil Company, Los Angeles, California
Exploration Work in California during 1940

The discovery rate for the year 1940 in California declined. This followed and was accompanied by a decrease in geophysical work and exploratory drilling while geological employment remained approximately the same. Only one new oil field was discovered and there were a few areal and depth extensions of known fields. Several wildcat wells were completed as small producers in what, at present, appear to be non-commercial accumulations.

Drilling within fields increased California's potential production but additions to reserves has lagged behind withdrawals and lowering of estimates in fields under development. Faster drilling has accelerated the approach to a drilled up status for California fields. An attempt is made to arrive at the cost and length of payout time for an average top allowable well as an indication of the optimum expectancy for operating capital put into development wells.

Methods of attack now being used on the California exploration problem are referred to briefly.

66. ROLLIN ECKIS, Richfield Oil Corporation, Bakersfield, California
Stevens Sand, Southern San Joaquin Valley, California

The Stevens sand, first penetrated in 1936 by the Shell Oil Company's discovery well at Ten Sections oil field, is present beneath a large part of the southern San Joaquin Valley in Kern County, California. It has a maximum known thickness of about 2,000 feet, and at present is yielding commercial production from seven different structures.

It comprises a series of more or less interconnected sands that lies below the top of a prominent chert zone within the upper Miocene. This paper deals primarily with the distribution, character and probable origin of the sand body.

67. E. W. GALLIHER, Barnsdall Oil Company, Los Angeles, California
E. R. ATWILL, Union Oil Company of California, Los Angeles, California
Progress of Stratigraphic Studies in California

Many geologists in California have been converted to the belief that the stratigraphic type of trap will provide a majority of future oil fields in the state. Therefore, considerable impetus has been given to the study of sedimentation from every possible approach.

This paper presents the various methods now used in California to study sedimentation and stratigraphy, describing briefly the results obtained to date and analyzing the future trend of this type of work.

68. R. W. SHERMAN, The British-American Oil Producing Company, Los Angeles, California
Del Valle Oil Field, Los Angeles County, California

The Del Valle field, located about 40 miles northwest of Los Angeles, California, was discovered by R. E. Havenstrite, operator, September 8, 1940. Production is 33 gravity oil from 300 feet of sand in two zones in the upper 1,200 feet of the Modelo (Miocene). The structure is a southeasterly plunging anticline closed against a fault to the west and probably also by San Gabriel fault which parallels its north flank. It is estimated that the field will produce 75,000 barrels per acre and exceed 500 acres in extent.

69. ALEX CLARK, Shell Oil Company, Inc., Los Angeles, California
Pre-Miocene Stratigraphy of Bakersfield Area, California

In the past 3 years exploratory wells drilled on the floor of the San Joaquin Valley near Bakersfield have penetrated the basement complex of pre-Cretaceous crystalline rocks at depths ranging from 9,280 to 13,970 feet. These wells have encountered a succession of Oligocene and Eocene marine sands and shales lying between the previously well known Miocene marine beds and the basement. A basal non-marine member of uncertain age lies below the marine Eocene and directly upon the basement.

The discovery of this succession of rocks is of considerable scientific and economic interest because no such rocks are present in the coutcrops 15–20 miles east of the wells. There, marine Miocene beds with a basal non-marine member rest directly on the basement complex. Marine Oligocene beds are absent in the outcrops everywhere along the east side of the San Joaquin Valley. Marine Eocene beds are absent for a distance of 140 miles along the east side of the valley from the vicinity of Pastoria Creek at the south end and northward to the San Joaquin River over 100 miles north of Bakersfield. Commercial quantities of oil or gas have not as yet been found in the pre-Miocene rocks in the Bakersfield area.

70. A. F. WOODWARD, Stanley & Stolz, Los Angeles, California
Recently Discovered Middle Miocene Production in Inglewood Oil Field

Miocene production has been extensively developed in almost every oil field in the Los Angeles Basin. The fact that the Inglewood field was one of the principal exceptions prompted the drilling of a deep test on the south flank of the Inglewood fold.

The test found the top of the Miocene at about 7,350 feet. The upper Miocene (Modelo) sediments consisted of shale, silty sand, and phosphatic nodular shale. A volcanic-sedimentary series encountered between 8,358–8,420 was believed to be of middle Miocene age. Middle Miocene (Topanga) silty sandstones and shales were found from 8,420 to 8,760 feet.

Production is coming from the lower part of the Modelo formation (upper Miocene) and also from the upper part of the Topanga formation (middle Miocene). This is believed to be the first middle Miocene production discovered in the Los Angeles Basin.

71. WILLIAM W. PORTER, II, consulting geologist, Los Angeles, California
PAUL P. GOUDKOFF, consulting geologist, Los Angeles, California
Age of Shale in Amoura-Uscari Area, Costa Rica

In Talamanca province on the Caribbean side of Costa Rica, microfauna in strata from the Amoura River a few meters from the mouth of Uscari Creek are lower Miocene in age, and are older than the Uscari formation as it is known from the publications of Olsson and Woodring. Some qualification is suggested as to future correlations with the Uscari formation because of the difference in age between strata of the Uscari-Amoura area in the field (not listed by Olsson or Woodring), and strata in other localities ascribed to the Uscari formation in the literature. The microfauna has a confusing similarity to pre-Miocene forms, but can be correlated with the lower Miocene of California.

72. EUGENE C. REED, assistant State geologist, University of Nebraska, Lincoln, Nebraska
Geologic Phases of Recent Oil Development in Southeastern Nebraska

73. GLENN G. BARTLE, University of Kansas City, Kansas City, Missouri
Effective Porosity of Gas Fields in Jackson County, Missouri

A study of four gas fields near Kansas City, Missouri, shows a production per acre varying between 400,000 and 2,000,000 cubic feet. Calculations of the space required

for this gas in reference to the average thickness of the gas-producing sand would indicate that the effective porosity of these fields varies between seven and eighteen per cent.

PAPERS ON PROGRAM OF DIVISION OF PALEONTOLOGY AND MINERALOGY

1. NORMAN D. NEWELL and BERNARD J. KUMMEL, University of Wisconsin, Madison, Wisconsin
Permian-Triassic Relations in Middle Rockies
2. NORMAN D. NEWELL, University of Wisconsin, Madison, Wisconsin
Myalinidae in Zonation of Late Paleozoic
3. ALFRED G. FISCHER, University of Wisconsin, Madison, Wisconsin
Preliminary Studies of Phosphoria Formation
4. HUGH FRENZEL, University of Wisconsin, Madison, Wisconsin, and MAURICE MUNDORF, Cincinnati University, Cincinnati, Ohio
Fusulinidae from Phosphoria in Montana
5. HAROLD B. RENFRO, University of Wisconsin, Madison, Wisconsin
Faunal Correlation of Satanka and Lykins Formations
6. J. HARLAN JOHNSON, Colorado School of Mines, Golden, Colorado
Calcareous Algae during Permian Time
7. J. HARLAN JOHNSON and M. E. DORR, Colorado School of Mines, Golden, Colorado
Permian Algal Genus Mizzia
8. CHARLES B. READ, geologist, United States Geological Survey
Sequence and Relationships of Late Paleozoic Floras of Southwestern United States (Published with permission of the Director, United States Geological Survey)
9. CHARLES B. READ, geologist, United States Geological Survey
Pennsylvanian Formations and Floral Zones in Central and Northern Appalachian Region (Published with permission of the director, United States Geological Survey)
10. BERNHARD H. KUMMEL, JR., University of Wisconsin, Madison, Wis.
New Eotriassic Cephalopod Zone in Idaho
11. EDWARD A. FREDERICKSON, University of Oklahoma, Norman, Oklahoma
Cambrian-Ordovician Boundary in Oklahoma
12. CHARLES E. DECKER, University of Oklahoma, Norman, Oklahoma
Cambrian Graptolites from Wilberns Formation of Texas
13. CHARLES E. DECKER, University of Oklahoma, Norman, Oklahoma
Extensiform Didymograptus-Tetragraptus Horizon in Oklahoma
14. CHARLES E. DECKER, University of Oklahoma, Norman, Oklahoma
Profusely Branched Ordovician Hydrozoan in Oklahoma
15. FRANK V. STEVENSON, Walker Museum of Paleontology, University of Chicago
Devonian Sly Gap Formation of New Mexico
16. THOMAS G. ROBERTS, University of Wisconsin, Madison, Wisconsin
Geographic Variation in Triticites Ventricosus
17. HENRY V. HOWE, Louisiana State University, Baton Rouge, Louisiana
Use of Soap in Preparation of Samples for Micropaleontologic Study
18. W. H. TWENHOFEL, University of Wisconsin, Madison, Wisconsin
Sediments of Little Long Lake, Wisconsin
19. S. W. LOWMAN, Shell Oil Corporation, Houston, Texas
Ecologic Relationships of Some Brackish-Water and Shallow-Marine Foraminifera of Louisiana
20. FRANK E. LOZO, Texas Christian University, Ft. Worth, Texas
Biostratigraphic Studies of Some Texas Comanche Foraminifera
21. BENJAMIN H. BURMA, University of Wisconsin, Madison, Wisconsin
Jurassic Unconformities in Eastern Wyoming and Western South Dakota
22. BENJAMIN H. BURMA, University of Wisconsin, Madison, Wisconsin
Observations on Ontogeny of Fusulinids
23. RAYMOND E. PECK, University of Missouri, Columbia, Missouri
Comatulid Crinoides from Lower Cretaceous of Texas
24. A. R. MORNHINVEG, Union Producing Company, Houston, Texas
Foraminifera of the Red Bluff
25. HENRY V. HOWE, Louisiana State University, Baton Rouge, Louisiana
Fauna of Oligocene Glendon Formation at Its Type Locality

26. FRED E. SMITH, Union Producing Company, Houston, Texas
Micropaleontology of Two Wells on Fort Morgan Military Reservation, Baldwin County, Alabama
27. J. A. CUSHMAN, Cushman Laboratory for Foraminiferal Research, Sharon, Mass.
Some Suggestions for Ecologic Studies of Foraminifera
28. JULIA GARDNER, geologist, United States Geological Survey, Washington, D. C.
Correlation of Lower Claiborne in Gulf Province (Published with permission of the director, United States Geological Survey)
29. R. W. HARRIS, University of Oklahoma, Norman, Oklahoma
Ostracoda from Subsurface Simpson of North Texas Fort Worth Syncline
30. R. W. HARRIS, University of Oklahoma, Norman, Oklahoma
W. H. THAMS, University of Oklahoma, Norman, Oklahoma
Simpson Ostracoda of Cumberland Area of Southern Oklahoma
31. RAYMOND C. MOORE, University of Kansas, Lawrence, Kansas
HARRELL L. STRIMPLE, University of Kansas, Lawrence, Kansas
New Blastoid from Upper-Middle Pennsylvanian Rocks of Oklahoma
32. RAYMOND C. MOORE, University of Kansas, Lawrence, Kansas
LOWELL R. LAUDON, University of Kansas, Lawrence, Kansas
Symbols for Crinoid Parts
33. RAYMOND C. MOORE, University of Kansas, Lawrence, Kansas
Erroneous Emendation of Generic Names
34. RAYMOND C. MOORE, University of Kansas, Lawrence, Kansas
HARRELL L. STRIMPLE, University of Kansas, Lawrence, Kansas
Tegminal Structure of Crinoid Genus Delocrinus
35. RAYMOND C. MOORE, University of Kansas, Lawrence, Kansas
RUSSELL M. JEFFORDS, University of Kansas, Lawrence, Kansas
Studies on Permian Corals

PAPERS ON PROGRAM OF SOCIETY OF EXPLORATION GEOPHYSICISTS

1. L. K. MOWER, Shell Oil Co., Inc.
Report on Organization of Southern Seismic Well Shooting Association
2. J. J. JAKOSKY, University of Kansas
Trends in Petroleum Exploration
3. ESME EUGENE ROSAIRE, Subterrex
Analysis of Refraction Collapse of 1930
4. C. A. SWARTZ and R. W. LINDSEY, Gulf Research and Development Co.
Reflected Refractions
5. F. F. CAMPBELL, Geophysical Research Corp.
Deep Correlation Reflections near Hoskins Mound Salt Dome
6. P. H. JAMES, Robert H. Ray, Inc.
Underwater Gravity Meter Equipment and Surveys
7. JOHN H. WILSON, Independent Exploration Co.
Gravity-Meter Survey of Wellington Field, Larimer County, Colorado
8. LOUIS B. SLICHTER, Massachusetts Institute of Technology
Seismic Studies of Large Quarry Blasts
9. N. A. HASKELL, Western Geophysical Co.
Relation between Depth, Lithology, and Seismic-Wave Velocity in Tertiary Sandstones and Shales
10. ETHEL WARD MCLEMORE and PAUL WEAVER
Crosbyton High, West Texas
11. L. L. NETTLETON, Gulf Research and Development Co.
Relation of Gravity to Structure in Northern Appalachian Area
12. GEORGE P. WOOLLARD, Princeton University
Trans-Continental Gravitational and Magnetic Traverse and Its Relation to Regional Geology
13. T. A. ELKINS, Gulf Research and Development Co.
Test of Quantitative Mountain-Building Theory by Appalachian Structural Dimensions
14. ROBERT H. MILLER, Western Gulf Oil Co.
New Gravitational Method of Defining Underground Structure

15. L. J. Neuman, consultant
Some Factors Affecting Resolving Power of Electrical Logging Methods
16. E. J. Stulken, Allen Academy (formerly Geophysical Service, Inc.)
Seismic Velocities in Southeastern San Joaquin Valley of California
17. W. R. Ransone, Geophysical Service, Inc.
Geochemical Well Logging
18. Paul Weaver, Gulf Oil Corp.
Theory of Distribution of Radioactivity in Marine Sedimentary Rocks
19. Roland F. Beers, Geotechnical Corp.
Radioactivity in Applied Geophysics
20. Bruno Pontecorvo, Well Surveys, Inc.
Radioactivity Analyses of Oil Well Samples
21. J. C. Barcklow, Lane-Wells Co.
Radioactivity Well Logs: Their Use and Application
22. M. Muskat and H. H. Evinger, Gulf Research and Development Co.
Current Penetration in Direct-Current Prospecting
23. N. R. Sparks, Stanolind Oil and Gas Co.
Note on Rationalized Velocity Depth Equation
24. Frederick Romberg, Geophysical Service, Inc.
Probable Errors of Delta-T Velocities
25. W. E. Steele, Jr., Independent Exploration Co.
Comparison of Well Survey and Delta-T Velocities
26. D. S. Hughes, Shell Oil Co., Inc.
Analytical Basis of Gravity Interpretations
27. James D. Hudson, Robert H. Ray, Inc.
Practical Principles of Gravity Interpretation with Illustrations
28. Joseph L. Adler, Independent Exploration Co.
Simplification of Tidal Correction for Gravity-Meter Surveys
29. Arnold J. F. Siegert, The Texas Co.
Determination of Bouger Correction Constant
30. D. H. Clewell, Magnolia Petroleum Co.
Problems in Temperature Control of Gravity Meters
31. Esme Eugene Rosaire, Subterrex
Prospecting Effectiveness
32 Joseph A. Sharpe, Joint Geophysical Laboratory, Stanolind Oil and Gas Co., and Western Geophysical Co.
Observations of Ground Motion near Exploding Charge
33. H. R. Prescott, Continental Oil Co.
Seismic Receptors
34. Merle C. Bowsky, Lane-Wells Co.
Effect of Mud Resistivities on Intensities of Electrical Logs
35. Norman Ricker, Carter Oil Co.
Note on Determination of Velocity of Shale from Measurement of Wavelet Breadth
36. H. E. Banta, Independent Exploration Co.
Refraction Theory Adaptable to Seismic Weathering Problems
37. Leo Horvitz, Subterrex
Analytical Technique for Determination of Saturated Hydrocarbons in Sediments
38. Leo Horvitz, Subterrex
On Geochemical Prospecting II
39. E. F. Neuenschwander and D. F. Metcalf, Humble Oil and Refining Co.
Study of Electrical Earth Noise
40. Eugene McDermott and D. S. Renner, Geophysical Service, Inc.
Seismic Recording Attenuators
41. J. D. Eisler, Stanolind Oil and Gas Co.
Direct-Reading Phase Shift Meter
42. Alexander Wolf, The Texas Co.
Device for Computing Seismic Paths
43. C. A. Heiland, Colorado School of Mines
Decimal Classification System for Geophysical Exploration
44. Alfred Wolf, Geophysical Research Corp.
Limiting Sensitivity of Seismic Directors
45. Morton Mott-Smith, Independent Exploration Co.
Curved-Path Methods Applied to Verticals and to Wide-Shot Spreads

46. R. G. Piety, Phillips Petroleum Co.
Interpretation of Transient Response of Seismograph Instruments
47. C. H. Dix, Socony-Vacuum Oil Co.
Notes on Refraction Prospecting

MINUTES, TWENTY-SIXTH ANNUAL BUSINESS MEETING RICE HOTEL, HOUSTON, TEXAS

APRIL 2–4, 1941

L. C. Snider, *presiding*

The meeting was called to order at 1:30 P.M., April 2, 1941, by L. C. Snider, president.

1. *Resolutions committee.*—The president appointed a resolutions committee composed of A. R. Denison, C. R. McCollom, and J. R. Lockett.

2. *Nominations of officers.*—The president called for nominations of officers of the Association for the ensuing year. The following nominations were made.

For president:	Edgar W. Owen, nominated by John G. Bartram
	Fritz L. Aurin, nominated by Glenn C. Clark
For vice-president:	Earl B. Noble, nominated by George Sawtelle
For secretary-treasurer:	Edmond O. Markham, nominated by E. Floyd Miller
For editor:	W. A. Ver Wiebe, nominated by M. G. Cheney

3. *Ballot committee.*—The president appointed a ballot committee composed of W. B. Wilson, H. B. Fuqua, and Hal P. Bybee.

The meeting was recessed at 2:15 P.M. until 1:30 P.M., April 4, 1941.

The recessed meeting was called to order at 1:30 P.M., April 4, 1941, by L. C. Snider, presiding, Edgar W. Owen serving as secretary.

4. *Reading of minutes.*—It was moved, seconded, and carried that the minutes of the annual meeting held at Chicago, Illinois, April 10–12, 1940, be not read since they have been published in the *Bulletin*.

5. *Mississippi Geological Society affiliation.*—It was moved, seconded, and carried that the request of the Mississippi Geological Society for affiliation with the Association be granted.

6. *Report of officers.*—The reports of president L. C. Snider, secretary-treasurer Edgar W. Owen, and editor W. A. Ver Wiebe were presented (Exhibits I, II, III).

7. *Report of special committee on new method of electing officers.*—It was moved and seconded that the recommendation of the business committee be adopted, not to approve the report of the special committee on a new method of electing officers (Exhibit IV). Motion was carried by a vote of 76 *for*, 38 *against*.

[The reports of the special committee on college curricula in geology, F. H. Lahee, chairman; of the research committee, A. I. Levorsen, chairman; of the representaive of the Association on the National Research Council Division of Geology and Geography, A. I. Levorsen, representative; of the committee on geologic names and correlations, John G. Bartram, chairman; and of the committee for publication, R. E. Rettger, chairman, appear as Exhibits V, VI, VII, VIII, IX, respectively.]

8. *Report of the resolutions committee.*—It was moved, seconded, and carried that the report of the resolutions committee (Exhibit X) be adopted.

9. *Report of ballot committee.*—

Total ballots cast		548
For president		
Edgar W. Owen	331	
Fritz L. Aurin	217	

10. *Introduction of new officers.*—The newly elected officers of the Association were introduced by retiring president Snider.

11. *Reports of committees.*—Motion was made, seconded, and carried that the reports of all standing committees and of all special committees, except that of the special committee to recommend a new method of electing officers, be approved and published in the *Bulletin.*

12. The twenty-sixth annual meeting adjourned at 2:30 P.M.

L. C. Snider, *president* Edgar W. Owen, *secretary*

Exhibit I. Report of President

(Year ending April 4, 1941)

The twenty-fifth year of the American Association of Petroleum Geologists closes with the Association at its peak of membership, with the largest volume of its *Bulletin* published, and with considerably the largest annual meeting.

The reports of the secretary-treasurer and editor give the details in regard to membership, finances, and publications. It is unnecessary to repeat any of this information but particular attention may be called to the fact that none of the special publications for which plans were made by former executive committees reached completion during the year. The stock of several of our older publications is exhausted so that our income from sale of publications is and will be considerably less than usual until new volumes are issued. It may also be noted that the rate of income on our investments is very low. In spite of these conditions, the present executive committee feels that the year has been a fairly satisfactory one financially as well as from the standpoint of increase in membership and of material available for the *Bulletin.*

The year passed without any particularly striking events. The various committees functioned in their usual efficient manner as did also the Association office under the direction of the business manager.

Without detracting in any measure from the work of others, particular mention may be made of the activities of the research committee under the chairmanship of A. I. Levorsen. Besides arousing and maintaining interest in research in other ways, this committee has added a fourth day to the officially recognized three days of the annual meeting.

The special committee on college curricula in geology, Frederic H. Lahee, chairman, has made considerable progress in a difficult task. Under the terms of our constitution and by-laws, the term of this committee expires with this meeting, but its work should be continued and there is no doubt as to its being reappointed.

Considerable attention was given during the year to the Association's participation in the preparation of the National Roster of Scientific and Specialized Personnel. This subject has been dealt with at some length in the presidential address.

The fundamental importance of the relationship of the Association to its division, the Society of Economic Paleontologists and Mineralogists, and to its sections and affiliated societies, has been fully recognized by the present executive committee. Your president and vice-president visited most of the societies during the year. Their feeling of pleasure over their reception on such visits is tempered with regret that all the affiliated societies could not be visited.

Before relinquishing his office, your president wishes to express his deep appreciation for the honor you have bestowed upon him, and for the gratifying coöperation he has had from all with whom he has been associated in the year's work. He also desires to acknowledge publicly his indebtedness to his employers whose considerate attitude toward the Association and its work has made his presidential year a pleasant one in all its aspects.

L. C. SNIDER, *president*

EXHIBIT II. REPORT OF SECRETARY-TREASURER
(Year ending April 4, 1941)

MEMBERSHIP

The substantial growth in membership, which has prevailed for the past 5 years, continued during 1940 and has extended into 1941. The net addition of 234 members during the past year represents a 7 per cent increase in comparison with a 10 per cent increase (289 members) in the previous year. The total membership of 3,474 on March 1, 1941, constitutes another all time high. A majority of the new members elected have been associates. However, an unusually large number of our associates of a few years' standing made application for transfer to active membership and have been advanced to the status of full members. As a result, the percentage of associates has declined from 23 per cent to 22 per cent of the total membership. Geographical distribution of our members remained practically unchanged. Tables I, II, and III present comparative data on the growth, status, and distribution of members hip. The qualifications of the new members received during the past year continued to be of a very high order.

Several of our most valued members have passed away during the year and their loss will be felt keenly by the Association. These are:

Honorary—Campbell, Marius R., December 8, 1940
Active— Anderson, G. E., September 1, 1940
Chevalier, Jerome A., July 15, 1940
Handley, Howard W., October 24, 1940
Hopkins, Edwin B., July 5, 1940 (former vice-president)
Myers, Thurman H., December 9, 1940
Postley, Olive C., January 14, 1941
Prettyman, T. M., November 2, 1940
Sawyer, Roger W., March 16, 1941
Soper, Ralph H., September 23, 1940

FINANCES

The annual audit, which was published in the March *Bulletin*, showed the status of Association finances and the operating statement for 1940. Tables IV-IX, inclusive, furnish additional information and offer a comparison with past years.

The Association again operated at a profit which resulted in a slight addition to our surplus. There were no unusual items of income or expense during the year. The favorable financial record reflects the efficient work of the business manager and his staff.

The cost of the *Bulletin* accounts for a large part of the total expenses of the Association. The last volume of the *Bulletin* was by far the largest in total pages and number of copies in our history. A slight increase in printing costs, the use of more costly illustrations, and the expanded size of the volume resulted in an increased total expenditure for the year and a slightly higher cost per copy (see Table VIII).

Satisfactory investment of our surplus has continued to be a problem. Several of our best bonds have been called for payment, and persistent high market prices have prevented their advantageous replacement by similar securities. In view of unsettled world conditions and the high price of gilt-edged securities, the executive committee has found it advisable to maintain a large part of our surplus funds in Savings Accounts bearing a very low rate of interest. These funds are readily available for advantageous investment at such future time as may prove propitious. On March 1, 1941, our investment account stood as follows.

Bonds	$24,988.20
Preferred stocks	5,771.99
Common stocks	26,456.16
Morris Plan Company deposit	4,396.18
Savings accounts	20,133.51
Total	$81,746.04

The present market value of the common stocks held in our investment account is considerably below their cost, but the market value of other securities is equal to or above cost. However, all of our common stocks are on a dividend-paying basis and furnish the major part of our income from investment.

Table X presents the budget for 1941. Under this budget a *Bulletin* is provided for which is comparable in size and quality to the last volume. The budget presupposes the continuation of all present Association activities with some allowance for their slight expansion.

Table XI is presented in an effort to simplify the operating statement for the past two years and furnish a comparison with the budget proposed for 1941.

EXECUTIVE COMMITTEE MEETINGS

The executive committee met in long sessions during our conventions in Chicago and Houston and held an additional meeting in Austin on October 18. In the interim, the officers have carried on much of the Association business through correspondence and informal meetings between various members of the executive committee.

EDGAR W. OWEN, *secretary-treasurer*

TABLE I

TOTAL MEMBERSHIP BY YEARS

May 19, 1917	94	March 1, 1930	2,292
February 15, 1918	176	March 1, 1931	2,562
March 15, 1919	348	March 1, 1932	2,558
March 18, 1920	543	March 1, 1933	2,336
March 15, 1921	621	March 1, 1934	2,043
March 8, 1922	767	March 1, 1935	1,973
March 20, 1923	901	March 1, 1936	2,169
March 20, 1924	1,080	March 1, 1937	2,331
March 21, 1925	1,253	March 1, 1938	2,646
March 1, 1926	1,504	March 1, 1939	2,951
March 1, 1927	1,670	March 1, 1940	3,240
March 1, 1928	1,952	March 1, 1941	3,474
March 1, 1929	2,126		

TABLE II

COMPARATIVE DATA OF MEMBERSHIP

	March 1, 1940		*March 1, 1941*	
Number of honorary members	16		15	
Number of life members	4		4	
Number of members	2,461		2,702	
Number of associates	759		753	
Total number of members and associates		3,240		3,474
Net increase in membership		289		234
Total new members and associates	316		325	
Total reinstatements	40		25	
Total new members and reinstatements		356		350
Applicants elected, dues unpaid	16		11	
Applicants approved for publication	45		28	
Recent applications	77		100	
Total applications on hand		138		139
Applicants for reinstatement, elected, dues unpaid	5		6	
Recent applications for reinstatement	1		2	
Total applications for reinstatement on hand		6		8
	March 1, 1940		*March 1, 1941*	
Applicants approved for transfer, dues unpaid	9		1	
Applicants for transfer approved for publication	40		62	
Recent applications for transfer on hand	9		37	
Total applications for transfer on hand		58		100
Number of members and associates resigned	7		24	
Number of members and associates dropped	51		82	
Number of members died	9		10	
Total loss in membership		67		116
Total gain in membership		356		350
Number of members and associates in arrears, previous year	116		136	
Members in arrears, current year	808		858	
Associates in arrears, current year	249		230	
Total number members and associates in arrears, current year		1,057		1,088
Total number members and associates in good standing		2,067		2,250

TABLE III

GEOGRAPHIC DISTRIBUTION OF MEMBERS

March 1, 1941

Alabama	9	Louisiana	186	Oklahoma	459
Arizona	1	Maine	1	Oregon	1
Arkansas	15	Maryland	4	Pennsylvania	66
California	424	Massachusetts	8	S. Carolina	1
Colorado	46	Michigan	36	S. Dakota	2
Connecticut	6	Minnesota	6	Tennessee	6
Delaware	2	Mississippi	33	Texas	1,164
Dist. of Columbia	41	Missouri	24	Utah	3
Florida	6	Montana	9	Vermont	1
Georgia	1	Nebraska	11	Virginia	2
Idaho	1	New Jersey	14	Washington	4
Illinois	123	New Mexico	24	West Virginia	19
Indiana	52	New York	92	Wisconsin	3
Iowa	7	N. Carolina	3	Wyoming	17
Kansas	138	N. Dakota	2		
Kentucky	16	Ohio	23		

Total members in United States 3,112

Alberta	21	England	14	Palestine	4
Angola	1	France	4	Papua	6
Arabia	1	Germany	9	Persian Gulf	8
Argentina	16	Guatemala	1	Peru	4
Australia	9	Haiti	2	Philippine Is.	5
Austria	1	Hungary	1	Poland	2
Barbados	1	India	4	Portugal	1
Belgian Congo	2	Iran	1	Roumania	5
Borneo	1	Iraq	5	Scotland	2
Brazil	1	Italy	3	Spain	1
British Columbia	1	Japan	2	Sumatra	12
Burma	2	Java	4	Switzerland	13
Canal Zone	3	Madagascar	1	Syria	3
Colombia	37	Mexico	8	Thailand	1
Cuba	6	Netherlands	9	Trinidad	11
Dominican Republic	5	Nicaragua	1	Turkey	2
Ecuador	7	New Zealand	12	Uruguay	1
Egypt	8	Ontario	4	Venezuela	73

Total members in foreign countries 362
Grand total 3,474

TABLE IV

COMPARISON OF ACCRUED INCOME BY CALENDAR YEARS

	1938	1939	1940
Dues			
Members	$22,170.00	$24,640.00	$26,590.00
Associates	4,408.00	4,756.00	4,734.00
Total	$26,578.00	$29,396.00	$31,324.00
Bulletin			
Subscriptions	$ 4,376.96	$ 4,645.43	$ 4,420.76
Advertising	7,093.72	8,651.75	7,199.03
Total	$11,470.68	$13,297.18	$11,619.79
Back Numbers, etc.			
Bound Volumes of Bulletin	$ 2,533.93	$ 3,044.70	$ 3,483.10
Back Numbers of Bulletin	858.10	1,284.93	2,042.94
Other Publications	66.34	74.88	86.49
Total	$ 3,458.37	$ 4,404.51	$ 5,612.53
Special Publications			
Structure Volume II	$ 439.52	$ 884.20	$ 40.60
Problems of Petroleum Geology	639.88	—	—
Geology of Natural Gas*	616.38	675.60	522.72
Geology of Tampico Region*	172.67	158.98	129.10
Index	115.04	55.62	51.10
Gulf Coast*	743.44	640.08	462.00
Struct. Evol. of Sou. California*	299.44	229.24	111.44
Tectonic Map*	21.90	21.45	24.20
Miocene Stratigraphy of California*	368.00	1,972.90	340.30
Recent Marine Sediments*	—	2,993.20	2,105.15
Total	$ 3,416.27	$ 7,631.27	$ 3,786.61
Other Income			
Convention Receipts (Net)	$ —	$ 808.66	$ —
Delinquent Dues Charged Off	118.00	297.00	332.00
Interest, General Fund	1,901.26	1,718.98	1,755.79
Interest, Research Fund	74.14	80.72	83.58
Interest, Publication Fund	437.66	387.45	478.19
Profit, sale of Investments, Gen. Fund	—	—	177.51
Profit, sale of Investments, Publ. Fund	—	—	45.00
Miscellaneous	83.33	157.20	96.85
Sale of Library	—	25.50	55.58
Members Reinstated	144.77	81.00	48.25
Inventory Increase	733.38	—	—
Contribution, Research Fund	300.00	—	—
Adjustment of stated value of Investments to lower of cost or market	—	472.97	—
Regional Cross Sections	—	—	534.55
Total	$48,715.86	$58,758.44	$55,950.23

* Income of Publication Fund.

TABLE V

Comparison of Accrued Expenses by Years

General and Administrative Expenses	*1938*	*1939*	*1940*
Salaries—Manager	$ 2,840.00	$ 3,225.00	$ 3,750.00
Clerical	5,762.62	5,543.10	5,831.90
Rent	1,500.00	1,500.00	1,500.00
Telephone and Telegraph	249.51	324.54	366.26
Postage	1,675.30	1,394.92	2,036.86
Office Supplies and Expenses	448.73	354.76	491.71
Printing and Stationery	408.05	321.91	241.78
Audit Expense	300.00	150.00	300.00
Insurance and Taxes	179.28	186.64	237.32
Convention Expense (Net)	80.84	—	55.61
Freight and Express	128.03	161.01	159.93
Bad Debts	408.76	750.07	857.01
Miscellaneous	360.29	173.05	158.76
Depreciation—Furn. and Fixtures	388.03	399.00	209.04
Investment Counsel	400.00	400.00	400.00
Loss on sale of Bonds, etc. (Net)	1,491.24	252.25	—
Excess of cost of Investments over lower of Cost or Market	5,718.43	—	2,500.53
Bass-Neumann Research Project	—	416.94	811.61
Van Tuyl-Parker Research Project	—	100.00	—
Tectonic Map of United States	—	300.00	—
Whitehead's Radioactivity of Oil and Gas.	—	—	300.00
Waldschmidt's Core Analysis	—	—	26.22
	$22,339.11	$15,953.19	$20,234.54
Less Expenses charged Soc. of Econ. Paleon. and Mineralogists	702.81	—	—
Total	$21,636.30	$15,953.19	$20,234.54
Publication Expenses			
Salaries—Manager	$ 3,000.00	$ 3,562.50	$ 3,750.00
Editorial	4,840.00	3,950.00	3,975.00
Printing Bulletin	12,778.54	15,274.68	17,914.26
Engravings	1,945.66	2,271.29	2,654.54
Separates	149.04	151.31	377.61
Stencils and Mailing	229.54	230.19	218.23
Binding Bulletins	491.10	623.55	583.79
Postage and Express (Bulletins)	962.08	1,180.04	1,232.36
Copyright Fees	24.00	24.00	24.00
Freight, Express, Postage (Other Publications)	460.02	240.76	187.88
Discounts	13.53	40.92	52.34
Purchase of Back Numbers	—	18.00	—
Bad Debts	7.19	67.33	—
Miscellaneous	10.59	20.88	21.75
Special Publications	4,134.86	4,200.03	348.81
Bulletin Inventory Decrease	—	1,676.22	678.50
Special Publication Inventory Decrease	—	443.96	2,262.40
Transloid Cross Sections	—	—	421.12
Total	$29,046.15	$33,975.66	$34,702.59
Total Expense	$50,682.45	$49,928.85	$54,937.13

TABLE VI

COMPARISON OF NET INCOME BY YEARS

	1938	*1939*	*1940*
Accrued Income	$48,715.86	$58,758.44	$55,950.23
Expenses			
General and Administrative	21,636.30	15,953.19	20,234.54
Publication	29,046.15	33,975.66	34,702.59
Total	$50,682.45	$49,928.85	$54,937.13
Excess Income over Expenses	$ 1,966.59	$ 8,829.59	$ 1,013.10

TABLE VII

INVESTMENTS

	Cost	*Market Value End of Year*
1938 Values		
General Fund	$49,438.27	$45,485.20
Publication Fund	11,843.40	11,634.90
Research Fund	1,896.05	1,738.55
Total	$63,177.72	$58,858.65
1939 Values		
General Fund	$58,341.06	$56,281.51
Publication Fund	12,412.50	12,090.87
Research Fund	2,249.14	2,072.89
Total	$73,002.70	$70,445.27
1940 Values		
General Fund	$62,907.09	$57,418.34
Publication Fund	16,481.17	14,275.03
Research Fund	2,332.72	2,293.97
Total	$81,720.98	$73,987.34

TABLE VIII

COMPARISON OF COST OF BULLETIN

	1938	*1939*	*1940*
Total Expenses	$23,939.45	$26,655.96	$30,146.00
Monthly Edition	3,900	4,400	4,700
Total Copies Printed	46,800	52,800	56,400
Total Pages Printed, Including Covers	2,174	2,374	2,624
Total Pages of Text	1,746	1,922	2,232
Total Cost Per Copy	0.512	0.505	0.535

TABLE IX

(Section 1)

SPECIAL PUBLICATIONS

	Structure Vol. II	*Geology Natural Gas*	*Geology Tampico Region*	*Gulf Coast Oil Fields*	*Total*
Inventory					
Dec. 31, 1939	$ 79.20	$2,376.00	$1,772.46	$1,272.37	$5,500.03
Dec. 31, 1940	54.00	1,952.00	1,690.02	1,016.15	4,712.17
Sales	40.60	522.72	129.10	462.00	1,154.42
Total Edition	2,500	2,500	1,575	2,510	
Copies on Hand					
Dec. 31, 1939	22	594	774	725	
Dec. 31, 1940	15	488	738	579	
Number of Pages	780	1,227	280	1,070	
Cost (inventory) per Copy	$3.60	$4.00	$2.29	$1.755	
Selling Price, when issued, per Copy	4.00	4.50	3.50	4.00	
Present Selling Price					
Members and Associates	8.00	4.50	3.50	3.00	
Non-Members	8.00	6.00	4.50	4.00	

TABLE IX

(Section 2)

SPECIAL PUBLICATIONS

	Comprehensive Index (Paper)	*Struc. Evolution Southern California*	*Tectonic Map of Southern California*	*Miocene Stratig. of California*	*Recent Marine Sediments*	*Total*
Inventory						
Dec. 31, 1939	$ 861.54	$ 67.58	$ 49.28	$2,346.30	$1,943.20	$5,267.90
Dec. 31, 1940	280.54	15.26	45.36	2,180.48	652.40	3,174.04
Sales	51.10	111.44	24.20	340.30	2,105.15	2,632.19
Total Edition	1,271	1,047	940	1,530	1,500	
Copies on Hand						
Dec. 31, 1939	519	62	616	948	694	
Dec. 31, 1940	169	14	567	881	233	
Number of Pages	382	157	—	450	736	
Cost (inventory) per Copy	$1.66	$1.09	$0.08	$2.475	$2.80	
Selling Price, when issued, per Copy						
Members and Associates	—	2.00	0.50	4.50	4.00	
Non-Members	—	2.00	0.50	5.00	5.00	
Present Selling Price						
Members and Associates	2.00	2.00	0.50	4.50	4.00	
Non-Members	3.00	2.00	0.50	5.00	5.00	

TABLE X

BUDGET

	Estimate for 1941
REVENUES	
Dues	$32,500.00
Bulletin	
Subscriptions	4,750.00
Advertising	7,000.00
Bound Volumes	2,600.00
Back Numbers	500.00
Special Publications	
Structure Vol. II	16.00
Geology of Natural Gas	440.00
Geology Tampico Region	150.00
Comprehensive Index	30.00
Gulf Coast Oil Fields	300.00
Struc. Evol. Southern California and Map	54.00
Miocene Stratigraphy	210.00
Recent Marine Sediments	500.00
Other Publications	200.00
Other Income	
Miscellaneous	750.00
Investments	2,000.00
Total	$52,000.00
EXPENSES	
General	17,500.00
Publication	32,000.00
Research	3,500.00
Special Volumes	4,500.00
Miscellaneous	500.00
Total	$58,000.00

TABLE XI

COMPARATIVE OPERATING STATEMENT

	1939	1940	Estimate for 1941
INCOME			
Dues	$29,396.00	$31,324.00	$32,500.00
Advertising	8,651.75	7,199.03	7,000.00
Subscriptions	4,645.43	4,420.76	4,750.00
Sale of Publications	12,035.78	9,933.69	5,000.00
Income from Investments	2,187.15	2,317.56	2,000.00
Miscellaneous	1,369.36	755.19	750.00
Total	$58,285.47	$55,950.23	$52,000.00
EXPENSES			
General	$14,960.26	$16,516.82	$17,500.00
Bulletin	27,579.19	30,782.13	32,000.00
Special Publications	4,200.03	957.81	4,500.00
Research	816.94	1,137.83	3,500.00
Miscellaneous	252.25	101.11	500.00
Total	$47,808.67	$49,495.70	$58,000.00
EXCESS OR DEFICIT	+$10,476.80	+$ 6,454.53	−$ 6,000.00
Adjustment to Inventory of Publications	− 2,120.18	− 2,940.90	+ 2,500.00
ACTUAL PROFIT OR LOSS	+$ 8,356.62	+$ 3,513.63	−$ 3,500.00
Adjustment of Investments to Market Value	+ 472.97	− 2,500.53	?
PROFIT—According to Auditor's Report	$ 8,829.59	$ 1,013.10	?

EXHIBIT III. REPORT OF EDITOR

The year 1941 brings to a close the fourth year of service of the present editor. The methods of procedure developed during that length of time differ only in detail from the methods adopted and used by his predecessors. A little more emphasis has been placed on letters to prospective authors and on the closely related work of the publication committee. The effect of this emphasis appears in the somewhat larger size of the monthly *Bulletin* and the somewhat more numerous Geological Notes. A vote of thanks is due to the group of associate editors, who have worked faithfully and done their work well. The sum total of the correlated efforts of the editorial group and the publication committee has always been directed toward the object of providing the greatest amount of entertaining and instructive reading for the greatest number of our members. That this ideal has been approximated is indicated by the letters received which express satisfaction with our selection of material and the comparative lack of letters of criticism.

The statistics prepared for the report of the editor last year have been continually kept up to date and furnish some interesting sidelights on the forces which operate to supply a group of ravenous readers with material for intellectual enjoyment. It is hoped, furthermore, that the publication of these statistics will be of service to future editors and allow them to concentrate on certain methods of approach. In Table I the number of articles printed in the *Bulletin* each year are shown. It should be pointed out that our year begins with the April number and ends with the March number of the succeeding year. It should also be emphasized that the articles listed are only the longer

papers of major character and the shorter articles which contain some important new contributions. The table does not include such items as Reviews, or materials published under the heading of Discussion, *et cetera*. Last year the number of major papers published was 76 and the number of Geologic Notes was 36. Table I also indicates the provenance of the articles which are published in the *Bulletin*. A study of the table will indicate that most of the papers come from the programs of the annual conventions, or rather are the manuscripts which form the basis of the oral presentations at the time of the annual conventions. For instance, the 25th annual convention which was held in Chicago listed 73 papers on its program, not counting those which were intended for publication in the *Journal of Paleontology* or the *Journal of Sedimentary Petrology*. Out of this total 44 manuscripts were sent in for publication. This is considerably more than half and thus exceeds the percentage from other previous years tabulated. The New Orleans meeting of 1938 had 99 papers on its program of which 51 were later published. The Oklahoma City meeting of 1939 had 70 papers on its program of which exactly half were published during the ensuing year and seven more during 1940. From this statement it appears that the manuscripts due to the annual conventions come to the desk of the editor rather promptly (most of them within 5 months) and are likely to appear in print before the time of the next succeeding convention. Only a very small percentage appears in the *Bulletin* of the following year.

TABLE I

SOURCE OF BULLETIN PAPERS

Year	*Number of Papers*	*Conventions*	*Spontaneous*	*Publication Committee*	*Editor*
1937	83	34	39	7	1
1938	92	49	27	11	5
1939	108	48	28	15	17
1940	112	44	35	25	8

The situation described seems to account for the rather definite seasonal character of manuscript accumulation. During the past year, for instance, we had on hand enough manuscripts to fill one *Bulletin* at the time of the 25th annual meeting in April, 1940. On July first we had enough to fill three numbers of the *Bulletin* and on January first 1941 we had enough to fill approximately six numbers. At the time of the present meeting in April, 1941, we have material on hand for three numbers, not counting the June number which is reserved for special articles on Recent Developments.

It will appear from a study of Table I that the publication committee is gaining momentum. This committee began to function during the year 1937, but did not get well started until the following year. It has members in all large districts and their duty is to encourage geologists who have followed up some special line of investigation to put their findings on record. The recent successes of the committee members are attested by the fact that no less than 25 papers were written at their behest. In fact this number is definitely conservative, for many of the papers which appear on the program of the annual convention are also due directly to the efforts of the committee. It becomes apparent from these data that the high standard of the papers in the *Bulletin* and the uninterrupted flow of similar papers can not be expected without the continued operation of the publication committee.

The statistics kept during the last 4 years provide another interesting set of data as set forth in Table II. In this table the source of the articles which are eventually printed in the *Bulletin* is indicated.

TABLE II

PROFESSIONAL SOURCE OF PAPERS

Year	*Number of Papers*	*Oil-Company Men*	*Consulting Geologists*	*Teachers*	*State Survey*	*Federal Survey*
1937	83	45	14	13	6	6
1938	92	41	16	16	9	9
1939	108	53	15	21	11	8
1940	112	53	22	19	13	5

This table reveals the fact that approximately half of the articles published in the *Bulletin* originate in the offices of oil companies in various parts of the world. During 1940 the percentage of papers which came from the pens of geologists who are doing consulting work increased to 20 per cent as compared with 15 per cent previously. Geologists who are teaching or doing research work in universities contribute a very similar percentage. The amount of material contributed by members of State geological surveys or bureaus and agencies of like character is apparently increasing slightly each year. About 12 per cent of the papers we published last year was sent in by technicians and geologists employed by such surveys.

In summary the statistics show that the number of papers has increased from 83 to 112 and the number of pages has increased steadily until 1940 when the average number of pages for each monthly *Bulletin* was 218. This does not mean that we have reached the peak of attainment. We still do not print all the information which is available and which the other members of our Association would like to see in print. New producing zones are still being discovered which no member seems to think are important enough to describe in a short note. The same applies to new deeper pay zones in old explored areas, to new correlations being worked out by local societies, to new bits of information on lithologic peculiarities of producing horizons and a multitude of other geological phenomena. This type of information is most interesting and valuable when it is fresh. Therefore, I would like to urge each and every member to becomes a reporter for the *Bulletin*. If you do not have time to write up the information you have discovered it can be turned over to one of our associate editors or to a member of the publication committee, who in turn will be glad to prepare it for publication.

It is pleasant to report that work on the four special volumes authorized by the executive committee is going forward at a good pace. The volume in which many oil fields will be described in which the oil is stored in stratigraphic traps appears to be one which will reach the publication stage rather soon. The symposium on Permian strata and oil pools in regions of Permian rocks, is being sponsored by a large and very enthusiastic group of authors. They are doing a prodigious amount of work and have innumerable problems to contend with. I am sure that our membership will be pleased with their symposium when it appears in print.

In order to furnish comparative data for past years the following additional tables have been prepared. They allow us to see how the papers published last year were distributed as to geography, as well as to see how the published material varies from month to month.

TABLE III

GEOGRAPHIC DISTRIBUTION OF MAJOR ARTICLES AND GEOLOGIC NOTES

California	14	Michigan	3
Texas, South	14	Mississippi	3
Texas, North	9	West Virginia	3
Texas, West	5	Wyoming	3
Oklahoma	7	Arkansas	2
Louisiana	5	Colorado	2
Pennsylvania	5	Iowa	2
New Mexico	4	New York	2
Kansas	3	Australia	2

One article for each of the following: Florida, Indiana, Illinois, Kentucky, Minnesota, Missouri, Nebraska, Montana, Ohio, Tennessee, Columbia, Venezuela, Canada, Trinidad.

TABLE IV

BULLETIN PAGES BY MONTHS IN 1940

	Majors	*Minors*	*Majors and Minors*	*Advertising and Misc.*	*Total*
Jan.	188	20	208	28	236
Feb.	150	50	200	36	236
Mar.	69	139	208	32	240
Apr.	114	34	148	28	176
May	117	71	188	28	216
June	173	31	204	32	236
July	173	23	196	28	224
Aug.	122	54	176	36	212
Sept.	147	29	176	32	208
Oct.	131	29	160	28	188
Nov.	154	50	204	28	232
Dec	111	53	164	52	216
Total	1,649	583	2,232	388	2,620
Monthly average	137.4	48.5	186	32.3	218.3

TABLE V

BULLETIN PAGES AND CONTENTS BY YEARS

	1937	*1938*	*1939*	*1940*
Pages, major articles	1,191	1,276	1,301	1,649
Pages, minor articles	450	470	621	583
Pages, majors and minors*	1,641	1,746	1,922	2,232
Pages, advertising, etc.	372	380	404	388
Total pages	2,013	2,126	2,236	2,620
Number illustrations	388	378	470	474
Number, major articles	70	70	60	88
Number, minor articles	83	70	92	82

* Minors: geological notes, study groups, discussions, reviews, memorials.

W. A. VER WIEBE, *editor*

EXHIBIT IV. REPORT (MINUTES) OF BUSINESS COMMITTEE

Rice Hotel, Houston, Texas, April 1, 1941

The meeting was called to order at 10:00 A.M. by W. B. Heroy, chairman. The following members were present.

Executive committee: L. C. Snider, John M. Vetter, Ed. W. Owen, W. A. Ver Wiebe

Business committee: W. B. Heroy, chairman; Albert Gregersen, vice-chairman; Edgar W. Owen, secretary

Members-at-large: Fritz L. Aurin, P. D. Moore, Urban B. Hughes, A. A. Baker, Raymond C. Moore

Division of Paleontology: Carey Croneis (represented by John R. Sandidge), H. B. Stenzel

District representatives:

Amarillo: C. Don Hughes (represented by E. A. Paschal)
Appalachian: Paul H. Price
Canada: Not represented
Capital: L. W. Stephenson
Dallas: W. W. Clawson (represented by John W. Clark)
East Oklahoma: N. W. Bass, Robert H. Wood (represented by R. J. Riggs), T. E. Weirich
Fort Worth: C. E. Yager
Great Lakes: N. W. Ballard, A. H. Bell
Houston: J. Boyd Best, R. L. Beckelhymer, Carleton D. Speed, Jr.
New Mexico: Delmar R. Guinn
New York: W. T. Thom, Jr.
Pacific Coast: H. K. Armstrong (represented by Walter A. English), H. L. Driver, E. C. Edwards (represented by Frank A. Morgan), R. G. Reese (represented by Albert Gregersen)
Rocky Mountain: C. E. Dobbin
Shreveport: C. L. Moody
South America: Not represented
Southeast Gulf: James H. McGuirt (represented by Chalmer J. Roy)
So. Permian Basin: Ronald K. DeFord (represented by Charles D. Vertrees)
South Texas: C. C. Miller, Stuart Mossom
Tyler: Edward B. Wilson
West Oklahoma: C. W. Tomlinson
Wichita: James I. Daniels
Wichita Falls: James F. Gibbs

1. *Seating of representatives.*—Motion was made, seconded, and carried that members of the business committee not present at roll call may be recorded by the secretary if they report to him at the close of the session.

Motion was made, seconded, and carried that alternates present without written credentials be seated at the meeting.

2. *Minutes of previous meeting.*—It was moved, seconded, and carried that the reading of the minutes of the last meeting of the committee be dispensed with, as they had been published in the *Bulletin*, and that the minutes of said meeting be adopted without change.

3. *Report of special committee to recommend a new method of electing officers, George S. Buchanan, chairman.*—The chairman read the following report of the special committee.

REPORT OF SPECIAL COMMITTEE TO RECOMMEND A NEW METHOD OF ELECTING OFFICERS

Gentlemen:

Reference is herein made to the minutes of the business meeting of the American Association of Petroleum Geologists, Stevens Hotel, Chicago, Illinois, April 9, 1940, which record the passage of an amendment instructing the president of the Association

to appoint a committee which would formulate and present a method of electing officers by mail ballot and present it in such fashion to the business committee at the 1941 annual business meeting that it could be brought to vote of the Association members.

President Henry Ley appointed the following committee.

George S. Buchanan, *chairman*

N. Wood Bass	J. V. Howell	John N. Troxell
Glenn C. Clark	L. C. Morgan	W. B. Wilson

This committee has met on a number of occasions during the past year and will make a unanimous report to the business committee of the American Association of Petroleum Geologists on April 1, 1941, at 10:00 A.M. In order better to prepare you and to acquaint you with the report of our committee we are sending out the following resolution in mimeograph form to members of the business committee. This may not be the precise final wording of the resolution as prepared by our committee but it will essentially be in this form. For your information we are also including the articles of the constitution pertaining to the present method of electing officers which would have to be repealed or changed to be in keeping with the new method herein expressed. These articles are as follows.

> ARTICLE IV, Section 2. The officers shall be elected annually from the Association at large by written ballot deposited in a locked ballot box by those members, present at the annual meeting, who have paid their current dues and are otherwise qualified under the constitution. Each candidate, when voted for as a candidate for the particular office for which he is nominated, shall be thereby automatically voted for as a candidate for the executive committee for one year, except that candidates for the presidency shall be automatically voted for as candidate for the executive committee for two years.
>
> ARTICLE IV, Section 8. The officers shall assume the duties of their respective offices immediately after the annual meeting in which they are elected.
>
> ARTICLE VI. The Association shall hold at least one stated meeting each year, which shall be the annual meeting. This meeting shall be held in March or April at a time and place designated by the executive committee. At this meeting the election of members shall be announced, the proceedings of the preceding meeting shall be read, Association business shall be transacted, scientific papers shall be read and discussed, and officers for the ensuing year shall be elected.

RESOLUTION

RESOLVED: That Section 2 of Article IV of the Constitution of this Association be amended to read as follows.

Section 2. The officers shall be elected annually from the Association at large in the following prescribed manner.

A. *Electors.*—All members of the Association qualified under the constitution who have paid current dues shall be entitled to nominate and vote at each election.

B. *Nominations.*—Nominations for officers may be made from the floor at each annual meeting of the Association at the time designated therefor in the official program of the meeting. Nominations shall be called for and the electors present shall nominate such candidates for such offices in the Association as they desire. Each candidate when nominated and voted for as a candidate for a particular office shall be thereby automatically nominated and voted for as a candidate for the executive committee for one year, except that candidates for the presidency shall be automatically nominated and voted for as a candidate for the executive committee for two years.

C. *Ballots.*—At the close of the meeting at which candidates have been nominated, the secretary-treasurer of the Association shall prepare an official ballot including the names of all offices for which candidates have been nominated, and the names of such candidates. The ballots shall provide a blank space under each office name for writing in the names of members other than those who have been formally nominated.

D. *Balloting.*—Within thirty days after the close of said nominations, such printed ballot, together with a return-address, business-return envelope, shall be mailed by the secretary-treasurer, first class mail, to each elector-member of the Association at his address as shown by the Association records. The ballots shall not be signed but the return envelopes shall be numbered so as to guarantee the honesty of the poll and preserve the secrecy of the ballot. The ballots shall be marked by the electors or names written into the ballot in the spaces provided and returned to the secretary-treasurer of the Association within a period of sixty days from the date of mailing.

E. *Count.*—At the close of the balloting, within the time designated, an election committee consisting of three members, one of whom shall be the secretary-treasurer of the Association, shall open, count and tabulate the results. Any names written into the ballot for any office shall be counted and tabulated in the same manner as those candidates who have been formally nominated and whose names appear on the printed ballot. The election committee shall report to the president the number of votes cast for each office and he shall declare the candidate for each office receiving the highest number of ballots elected; he shall notify the successful candidates of their election and shall announce the results of the election through the Press and the Association's *Bulletin*.

F. *Term.*—The officers so elected shall serve for a term of one year commencing at the close of the annual meeting following the election; pending the assumption of their respective duties at that time, they shall be designated "Officers Elect" but shall have no added voice, powers or duties by reason thereof.

BE IT FURTHER RESOLVED: That Section 8 of Article IV be repealed to become effective at the close of the 1942 annual meeting.

BE IT FURTHER RESOLVED: That Article VI of the said Constitution be amended by striking the words "for the ensuing year" from the last clause thereof, and the word "nominated" substituted for "elected."

BE IT FURTHER RESOLVED: That these amendments, when passed, shall take effect after the election of officers at the 1941 annual meeting and shall first apply to the election of officers whose terms shall commence at the close of the 1943 annual meeting.

GEO. S. BUCHANAN, *chairman*

ANALYSIS OF METHODS OF NOMINATING AND ELECTING OFFICERS IN NINE SCIENTIFIC SOCIETIES

NOMINATIONS

	From Convention Floor	*Council or Executive Committee*	*Special Committee*	*Petition by Members*	*Local Divisions*	*Individual Members*
Geol. Soc. Amer.		×		× (25)		
Amer. Chem. Soc.					×	×
Soc. Ex. Geophy.			×	× (20)		
Inst. Radio Eng.		×		× (35)		
Amer. Physical Soc.		×				× (20)
A. A. A. S.		×				
A. A. P. G.	×					
Econ. Pal. and Min.			×			
Soc. Econ. Geol.			×	× (10)		

ELECTIONS

	At Convention	*Mail*	*Proxies Permitted*	*Council*
Geol. Soc. Amer.		×	×	
Amer. Chem. Soc.				×
Soc. Ex. Geophy.		×		
Inst. Radio Eng.		×		
Amer. Phys. Soc.		×		
A. A. A. S.				×
A. A. P. G.	×			
Econ. Pal. and Min.		×		
Soc. Econ. Geol.		×		

ELECTION IN ADVANCE

	At Least 6 Months	*Presidential Election 1 Year*	*Retiring V.P. Must Be Nominee for President*
Amer. Chem. Soc.		×	
Soc. Econ. Geol.	×		
Soc. Ex. Geophy.			×

It was moved, seconded, and carried that the report of the special committee as presented by George S. Buchanan be accepted, that it be placed in the records, and that the business committee express its thanks to the special committee for its work in the preparation of the report.

It was moved, seconded and carried that paragraph "C" of the report be amended by the addition, at the end of the first sentence, of the following words, "and the names of such candidates."

It was moved and seconded that the ballot for the election of such officers carry a brief biography of each candidate from the standpoint of previous service to the Association. On call for division the vote was 9 in favor and 20 opposed, and the motion was lost.

It was moved and seconded that the business committee transmit the report of the special committee to the business meeting of the Association, with the recommendation that it be not approved.

As an amendment to this motion it was moved and seconded that the words "with the recommendation that it be not approved" be stricken from the motion. After discussion the amendment was lost, with 9 votes in favor and 22 opposed. The previous motion was then carried, the vote being 23 in favor and 12 opposed.

4. *Report of special committee on college curricula in geology, F. H. Lahee, chairman.*—After the reading of the report it was moved, seconded, and carried that it be accepted and referred to the general business meeting of the Association, with the recommendation that it be not read but that it be published in the *Bulletin.*

It was moved, seconded and carried that the business committee recommend to the executive committee that the work of the special committee on college curricula in geology be continued for another year.

The business committee thereupon recessed until the afternoon session.

(Recess)

The meeting was called to order at 2:15 P.M. by W. B. Heroy, chairman.

5. *Report of research committee, A. I. Levorsen, chairman.*—After the presentation of this report it was moved, seconded and carried that the report be accepted and referred to the general business meeting, with the recommendation that it be not read but that it be published in the *Bulletin.*

6. *Report of representative to the Division of Geology and Geography, National Research Council, A. I. Levorsen.*—After the presentation of this report it was moved, seconded and carried that the report be accepted and referred to the general business meeting of the Association, with the recommendation that it be not read but that it be published in the *Bulletin.*

7. *Report of committee on geologic names and correlations, John G. Bartram, chairman.*—After presentation of this report it was moved, seconded and carried that the report be accepted and referred to the general business meeting of the Association, with the recommendation that it be not read but that it be published in the *Bulletin.*

8. *Report of committee on applications of geology, Carroll E. Dobbin, chairman.*—Mr. Dobbin reported orally on the work of the committee, and it was moved, seconded and carried that his report be accepted.

9. *Report of committee for publication, Robert E. Rettger, chairman.*—After presentation of this report it was moved, seconded and carried that the report be accepted and referred to the general business meeting of the Association, with the recommendation that it be not read but that it be published in the *Bulletin.*

10. *Relations of the Society of Economic Paleontologists and Mineralogists.*—John R. Sandidge read a letter to the executive committee of the Association, signed by the Council of the Society, which discussed problems that had arisen in the operation of the Society and in its relations with the Association. It was stated that the funds of the Society had become inadequate for the publication in the *Journal of Paleontology* of the manuscripts received by the Society, and it was requested that the Association contribute to the Society the sum of $1,100 annually for this purpose. After discussion it was moved,

seconded, and carried that the business committee recommend to the executive committee that the Association contribute $1,100 for 1941 to the Society of Economic Paleontologists and Mineralogists to facilitate adequate publication of paleontological papers.

The Society also called attention to the publication in the *Bulletin* of various papers containing descriptions of fossils and expressed the view that such papers should be published in the *Journal of Paleontology*. After considerable discussion it was moved, seconded, and carried that the business committee recommend to the executive committee that the Association adopt as a policy the principle that the editor should decline to accept for publication in the *Bulletin* any descriptions of fossils. The motion was carried by a vote of 24 in favor and 4 opposed.

The meeting of the business committee thereupon adjourned.

W. B. Heroy, *chairman* Edgar W. Owen, *secretary*

Exhibit V. Report of Special Committee on College Curricula

The committee on college curricula was appointed to find out to what extent present college training of young men, who become petroleum geologists, may be inadequate, and to suggest changes which might more nearly satisfy modern requirements. Approaches to this problem have been made in three directions.

First, a questionnaire was sent to each of some 60 oil-company chief geologists and district geologists all of whom have wide contact with young graduate geologist employees, and who have ample opportunity, therefore, to appraise the character of modern college training in geology.

Second, a questionnaire was sent to each of 35 or 40 consulting geologists, men who have had an excellent opportunity to evaluate their own geological education in comparison with that now offered in college curricula.

Third, college catalogues descriptive of the courses offered in forty-four institutions in different parts of the United States were distributed to each of the eleven members of the committee, and these catalogues were carefully studied and the curricula were analyzed and compared. In most cases these institutions were listed in Marsh's *American Universities and Colleges*[1] as having granted the degree of Ph.D. in geology during the decade from 1929–30 to 1938–39.

The results of the committee's study of these questionnaires and catalogues are here summarized. It is to be understood, however, that this is in the nature of a progress report, for there is much that remains to be done.

In the replies to the two sets of questionnaires, the following points were stressed.

1. In the training of many graduates within recent years there has been observed an insufficient grounding in one or more of the basic subjects of mathematics, physics, chemistry, and English composition. The recommendation is made that requirements in these subjects be strengthened. Several correspondents suggested, also, a course in public speaking.

2. Too specialized training in the few branches of geology that apply directly to oil exploration does not produce as efficient a petroleum geologist as

[1] Edited by Clarence Stephen Marsh. 4th ed. (1940). Published by the American Council of Education, Washington, D. C.

a broader foundation in all the main branches of this science. For example, the man who has studied igneous and metamorphic rocks and their modes of occurrence, as well as sedimentary rocks and stratigraphy, will probably be more useful and more capable than one who has specialized on sedimentary rocks.

3. This does not mean, however, that sufficient attention is now being given to sedimentation. There is a noticeable deficiency, among graduates in geology, in understanding the principles of sedimentation.

4. Candidates for the degree in geology should have had courses in drafting, surveying, botany, zoölogy, and geophysical methods (see following).

5. By all means training in field mapping should be expanded. This was emphasized by a large majority of those who replied to the questionnaires. A minimum of two summer field courses should be required.

6. Too little attention seems to be given to the teaching of logic and the ability to reason; and too much time is apparently spent in mere memorizing of facts.

7. A 5-year course is much to be preferred to a 4-year course in preparation for the B.S. degree in geology. In fact, many of the correspondents favored requiring 5 years as the minimum period for a candidate who expects to enter petroleum geology.

The committee's study of the 44 catalogues led to the following conclusions and suggestions.

1. Classification of institutions from which a majority of petroleum geologists have graduated in recent years may be roughly made as follows.

a. Those institutions which place the emphasis on geological instruction in the graduate years, with broad training in fundamentals and electives in the undergraduate years.

b. Those institutions which graduate many students with what may be called the "standard B.S. degree in geology," or with an A.B. degree which has been made very similar in its requirements; in general the specifications for the degree include one year each in physics, surveying, mathematics, and chemistry, one or more years of a foreign language, and courses in most phases of geology; the essential characteristic of the course is a fairly broad but not rigorous preparation in basic sciences and considerable specialization in geology.

c. Those institutions which offer a curriculum in geological engineering, including a considerable number of strictly engineering subjects such as mechanics, strength of materials, thermodynamics, hydraulics, *et cetera*, greater emphasis is placed on physics, chemistry, and mathematics than in the curriculum for the "standard B.S. degree," and there are correspondingly fewer courses in the humanities.

d. Those institutions which place special emphasis on the basic sciences of chemistry, physics, and mathematics in their undergraduate curriculum of geology; the first 2 years may be largely devoted to these studies, whereas considerable time is given to geology in the last 2 years; graduate work is offered and encouraged.

2. There is great diversity, or lack of uniformity, among the 44 institutions, in respect to the various geological courses required or recommended for a geology major leading to the B.S. or B.A. degree; and the same may be said of the basic or fundamental courses and the electives similarly required or recommended.

3. With reference to particular subjects, the committee draws these conclusions.

a. English composition should be given more attention, with required courses in this subject, or required supervision of the manner of writing theses in other subjects, not only in the Freshman year, but throughout the undergraduate period. That this need is becoming increasingly evident is indicated by the fact that one of the major universities plans hereafter to give an examination in English composition to candidates for the higher degrees in all sciences.

b. For the science of modern geology, whether applied or not, there should be thorough training in mathematics, certainly through analytical geometry and probably through calculus; in physics; and in chemistry—qualitative, quantitative, and physical.

c. Descriptive geometry should be required since it assists the student to imagine in three dimensions, an ability which is very essential in geology. Professor Soper states that only 3 out of the 44 institutions require descriptive geometry for a geology major.

d. At least one modern language should be required, the choice being stated by some as between German and French, but other members pointing out the growing importance of Spanish.

e. More attention should be given to the study of sedimentation.

f. The curriculum in geology should most certainly provide a course on geophysical methods, a course which ought to be required of all candidates for the degree in geology. As was well put by the Geophysics Courses Committee of the A.I.M.E., in its report of February, 1941, "the practitioner of geophysical prospecting utilizes principles, techniques, and instruments of physics, but he is doing so for the purpose of obtaining geological data. The end point of his endeavors is the presentation of geological deductions." So widely is geophysics being applied now, for pure research as well as for commercial purposes, in subsurface geology, that an understanding of its methods and scope is almost indispensable in the training of a geology major.

4. The committee feels strongly that insufficient opportunity is provided for students to study geology in the field. Some colleges offer or require one summer course of 6 weeks; others require field mapping in 2 summers. Many apparently provide no field work during the fall, winter, and spring terms. We recommend that properly conducted field trips be required each year when geology is included in the curriculum, in both fall and spring terms, and, in addition to these trips, at least two summer courses of 6–8 weeks each.

5. Because of the cost and other difficulties contingent on a summer field course, we strongly urge coöperation between groups of universities in conducting such courses. If properly organized, such a program of field work could be arranged to provide a variety of geologic phenomena in different localities, and the students could benefit by instruction from a number of different specialists, each in his own province. Equivalent credit could be given in each of the coöperating colleges.

6. In general the committee favors a curriculum that is largely planned, although provided with a few elective opportunities to suit individual needs. We feel that the severe demands of the science practically require planning in order to give the graduate geologist adequate training for his work.

7. The committee favors, as a minimum, a 5-year curriculum for a student who intends to become a petroleum geologist. Four years are too short to pro-

vide time for any but the most essential courses. A 4-year graduate is definitely lacking in some essential phases of training.

8. The committee believes that there is a real opportunity for improvement in the coöperation between different departments in the same institution. For example, there should be close contact between the geology and English departments; between the geology and chemistry departments; between the geology and physics departments; and so on. There is too much isolation of the departments, too little mutual effort on the part of the several interlocking departments to demonstrate to the student how the different sciences are interrelated. By intelligent integration of these departments of instruction not only might time be saved for better uses, but also the student's conception of the meaning of things might be greatly facilitated.

Summary.—We have presented a series of more or less disconnected suggestions in the foregoing review. It is our belief that more time can be given with advantage to this study and that this committee might logically offer for consideration the outline of a general 5-year program of study leading to a degree in petroleum geology. Such a program would have to be ideal. It would no doubt have to be modified for adjustment to the exigencies of other courses and other departments in any given institution. It would have to be planned irrespective of questions of financing. We recommend that the work of this committee be continued for the more thorough consideration of the many ideas offered herein and for preparation and discussion of a curriculum for training petroleum geologists.

L. T. Barrow
Walter R. Berger
Hal P. Bybee
Ira H. Cram
Winthrop P. Haynes
K. K. Landes
John T. Lonsdale
John D. Marr
E. K. Soper
W. T. Thom, Jr.
F. H. Lahee, *chairman*

Exhibit VI. Report of Chairman of Research Committee

The activities of the research committee may be divided into four general classes, as follows: (1) publications; (2) grants of financial aid; (3) conferences; and (4) annual evening round-table discussion. The work under each of these headings is described in the following paragraphs.

PUBLICATIONS

1. *Permian volume.*—Work on the Permian volume is progressing satisfactorily under the editorship of Ronald K. DeFord. His report follows.

The stratigraphic part of the Permian volume is being prepared by 14 committees. The area covered extends from Mexico on the south to Montana on the north and from Oklahoma on the east to Nevada on the west. Many typical columnar sections are already prepared in pencilled form; others are being prepared. Committee meetings, correlation meetings, and field trips are being held in connection with this work.

The paleontology of the Permian will be treated by about 20 specialists. All articles are assigned, and rough drafts will begin to arrive about May 1, 1941. It is planned to circularize the preliminary papers for criticism.

About half the articles for the historical and economic part of the volume are agreed upon and assigned.

Editing a symposium is always a slow and difficult business beset by mischances. As the usual exigencies are now aggravated by a wartime crisis, the editors can say only that they hope the Permian volume can be published in 1943.—Ronald DeFord.

2. *Stratigraphic type oil-field volume.*—The material for the Stratigraphic Type Oil-Field volume is coming along in good shape. There is now on hand

the equivalent of approximately 400 printed pages of typewritten material and well over 100 printed pages of drawings, maps, etc. Nineteen articles describing as many oil fields have been turned in, and between eight and ten are ready to be turned in within a few weeks. The material should all be in the hands of the business manager by June 1 and the book should be out some time during the coming fall. This volume contains only descriptions of oil fields which are of the stratigraphic type—the limiting factor being if one or more sides of production is bounded by an edge of porosity. It will follow the general plan of the "Structure volume" with which you are all familiar.

3. *Tectonic map.*—Much work has been done by our members in the way of sending in corrections to the preliminary tectonic map, copies of which were sent out to all of the affiliated societies. However, the compiling of the corrections by Philip King has been delayed due to the fact that most of the U. S. Geological Survey staff have been working on strategic mineral surveys and there has not been time to devote to redrafting the map for final publication. At the present time various plans for publication are being discussed, but no formal submission is possible chiefly for the reason that the method of printing—whether engraving, or photo-lithographing, or offset, or zinc etching—has to be decided upon and then the type of color to be used and how it is to be used—either by coloring the contour lines or shading various areas depending on age of datum horizon *et cetera.* Answers to many questions such as these have to be found before the compiling and other work can be started.

The research committee is agreed that the A.A.P.G. should publish this map if it has the opportunity. Before going further with this project, however, we would like to have an expression from the business committee as to whether they think in principle we should attempt to publish it if it should be offered to us.

4. *Time of migration and accumulation.*—This committee, which was organized about 5 years ago under the co-chairmanship of F. M. Van Tuyl and Ben H. Parker, completed its preliminary report. Their fifth annual report follows.

Since the submission of the Fourth Annual Report the copies of the manuscript on "The Time of Origin and Accumulation of Petroleum" circulated among the members of the research committee were returned to us with numerous comments and suggestions. These were incorporated in a revised copy which, under special arrangement with the research committee and committee for publication, has been published as Volume 36, Number 2, of the *Colorado School of Mines Quarterly*. This is now being distributed (March, 1941). The report comprises 180 pages including the index. Two thousand copies were issued. These are being sent to 450 regular exchanges of the *Quarterly* and to 700 members of the A.A.P.G. who placed orders in advance of publication at a special pre-publication price of $1.50. The regular price of this publication is $2.00.

It is hoped that this report will stimulate added interest in the problem and that many comments and statements based on observations will be submitted for inclusion in a later report.—F. M. Van Tuyl and Ben H. Parker, Golden, Colorado, March 24, 1941.

While the research committee had the authority to spend up to $200.00 in order to mimeograph this report, the money to be returned through the sale of the report, we thought it better to accept the offer of the *Colorado School of Mines Quarterly* wherein they agreed to publish the report as their April issue and to reduce the price from the regular price of $2.00 per copy to $1.50 as a pre-publication price available to members of the Association. This report has now been published and will be available at this meeting. I believe that everyone interested in the problem of migration and accumulation—and what pe-

troleum geologist is not?—will find much of interest and value in the report which this committee has made.

GRANTS OF FINANCIAL AID

Upon the recommendation of the research committee, the executive committee has authorized the following grants during the past year.

1. Tulsa Geological Society project: $1,500.—This is a coöperative project under the direction of L. Murray Neumann and the committee consists of four geologists and several chemists, the most active of the chemists being Harold Smith of the U. S. Bureau of Mines. They are studying the relations of crude oils to stratigraphy and are attempting, by careful geologic and chemical methods, to determine if there is any association of types of oil with certain types or ages of sediments. The appropriation of $1,500 which was to pay for the routine work in connection with the chemical analyses, has been used up and over 230 Hempel analyses have been made. There may be a small additional amount necessary to complete analyses of oil which have been collected but which have not been run. These analyses were made by the Bureau of Mines, Bartlesville station.

2. Roger Revelle and F. P. Shepard: $300.—This grant was made 2 years ago but as yet it has not been used. It was made for the purpose of developing a sediment trap for the work which they are doing in the vicinity of LaJolla, California. At present the project is temporarily stalled due to negotiations with the Federal Government over the planting of buoys. Considerable experimental work has been going on in the development of the trap but apparently so far it has not been necessary to use our funds.

3. W. A. Waldschmidt: $200.—A grant of $200 was made to Dr. Waldschmidt, of the Colorado School of Mines, for the purpose of examining cores of reservoir rocks from the Rocky Mountain area with a petrographic microscope. This money was in conjunction with other funds appropriated by several oil companies to make up the total necessary to pay for the laboratory work on the samples. Dr. Waldschmidt is reporting the results of his work at the Sedimentation conference and also on the technical program of this meeting.

4. Bailey Willis and George Stose: $1,000.—A grant of $1,000 has been made to Bailey Willis and George Stose for use in the completion of the revised Geologic Map of North America. This project was started through funds from the Geological Society of America and the American Philosophical Society, which funds were thought adequate to complete the work; however, it was found that due to the war the Canadian Survey would not be able to do the drafting necessary to put their part of the map in shape for the final engraving, without unnecessary delay. The money which was granted by the executive committee is to be used in so far as necessary to do the drafting of the Canadian portion of the map under the direction of Mr. Stose, of the United States Geological Survey, and such other uses as necessary to expedite the final publication of the map.

The map which is being revised was published originally in 1911 as a part of *Professional Paper 71* of the United States Geological Survey, and since then there have been new maps on the United States and Alaska published; a complete revision of the Geologic Map of Canada is in process; and much new data is available on Mexico and the Central American countries.

The completion of the revised map should be of great interest to those geologists interested in regional problems.

5. Clark Goodman and W. L. Whitehead: $300.—A grant of $300 was made to Clark Goodman and W. L. Whitehead to continue their work on the radioactivity of crude oils. Their original article was published in the September issue of the *Bulletin*. Their report of progress follows.

PROGRESS REPORT (March 27, 1941)

RADIOACTIVITY OF PETROLEUM AND NATURAL GAS

The first step in this research was the development of a simple, all-metal sampler suitable for the collection of oil and gas samples at atmospheric pressure. Four samplers of the type shown in Figure 1 were constructed from ordinary pipe fittings. When painted with several coats of glyptal, these samplers were found to be sufficiently vacuum tight for our purposes.

The sampling procedure, a data sheet, and a list of the suggested locations of samples are appended. It is anticipated that this wide variety of samples will provide a fairly broad reconnaissance of the subject. Duplicate samples of oil and gas are to be taken in each case.

To date only one set of samples has been measured. Separator samples of oil and gas from Lacey and Snider well No. 6, A-38 survey, Gregg County, Texas, producing from the Woodbine sand were obtained through the courtesy of the Gulf Oil Corporation. Radon measurements on the two gas samples are as follows.

Sample No.	*Volume in Cc.*	*Total Activity in 10^{-12} Curies*	*Specific Activity in 10^{-12} Curies per Cc.*
1	880	3.9	0.0044
3	880	4.7	0.0053
		Mean	0.0049

An unexpected difficulty has been encountered in the measurement of the activity of the oil samples. This oil appears to have a much higher retentivity for radon, that is, a lower emanating power, than any previously measured. The following measurements have been made.

Sample No.	*Volume in Cc.*	*Time in Days*	*Total Activity in 10^{-12} Curies*
2	Ca. 180	6.3	6.0
2	Ca. 180	7.2	5.9
2	Ca. 180	9.5	4.4
2	Ca. 180	16.5	3.7
4	180	12.3	6.3

Samples of the oil have been ashed, and the residue is being stored pending the re-establishment of radioactive equilibrium. The radium content of the oil will then be determined. This datum combined with further measurements on sample No. 2 should provide an unambiguous analysis of the relative contents of radon and radium in the oil. It is also hoped that subsequent samples will not be so troublesome.

Because the estimated reservoir gas/oil ratio is 360 cubic feet per barrel, the foregoing mean value of the radon in the natural gas corresponds with approximately 0.5×10^{-12} curies per gram of oil in the reservoir. This concentration is more than twice the average total radon content of the 7 oil samples previously studied (Bell, Goodman, and Whitehead, *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 24, 1940, p. 1537). Hence, if subsequent measurements support this single example, the radioactive content of natural gas may represent a large fraction of the total content of reservoir fluids.

Although the data are incomplete on the oil, unless considerably greater activities are observed, the geochemical effect of radioactivity must be considered to be a minor factor in the genesis of this crude oil.—CLARK GOODMAN and W. L. WHITEHEAD, March 27, 1941.

SUPPLEMENTARY REPORT (April 1, 1941)

Although it is premature to make definite predictions of future possibilities, it may be helpful to speculate on certain avenues which seem open to immediate advance. By measurement of the uranium-helium or the uranium-lead ratios in rocks it is possible to determine their "age-ratio." This determination affords a geologic time scale of acceptable accuracy. The technique for these measurements has been perfected for igneous rocks where substantial quantities of the constituents afford good accuracy. For sedi-

ments adequate resolving power is not yet available but it is anticipated that further development will bring these quantities within the scope of analytical technique.

The implications of this technique, when developed, are such that it is permissible to think of dating the top and the bottom of a sedimentary formation, thus yielding the time interval during which deposition occurred. There was also the thought that hydrocarbons may be traced from their present site, through channels of migration back to their original source. It might be possible to date the beginning and the end of periods of time which the hydrocarbons might have spent in their course from origin to accumulation provided these periods of time were of substantial duration. If no migration occurred this fact might also be inferred.

Before any considerable progress can be expected along these lines a great amount of work must be done in the measurement of radioactivity in wide range of materials. These include the entire stratigraphic sequence of sedimentary formations as well as the gaseous and liquid hydrocarbons associated with the sediments.—ROLAND F. BEERS.

CONFERENCES

A series of conferences was started last year on problems of fundamental interest to petroleum geology. These conferences were held the afternoon preceding the annual convention. They are being continued this year and are in session at the present time. They are as follows.

(1) "Sedimentation"—Wayne Galliher, leader; F. W. Rolshausen, assistant leader; W. C. Krumbein, assistant leader.
(2) "Origin of Oil"—M. G. Cheney, leader; W. W. Rand, assistant leader.
(3) "The Relation of Oil Analyses to Stratigraphy"—Murray Neumann, leader.
(4) "Oil Field Waters"—L. C. Case, leader.
(5) "Migration and Accumulation of Oil"—F. M. Van Tuyl, leader; Ben H. Parker, assistant leader.

These conferences are scheduled to run from 2:00 to 5:00 in the afternoon and are open to anyone interested in the problems discussed. It is thought that much good will come from this type of meeting where the combined experience of many years can be focused on a problem of fundamental importance. The research committee would be glad to organize other conferences if any group interested in any other problem wish to meet in this manner.

ROUND-TABLE DISCUSSION

For a number of years the research committee has scheduled a meeting on the evening prior to the annual convention for the discussion of some problem of fundamental interest. Last year at the Chicago meeting, the discussion subject was "Geochemical Surveying (Soil Analysis)." At this meeting, papers were presented by E. E. Rosaire and Eugene McDermott, followed by an hour's discussion which consisted of the answering of questions turned in by the audience.

Another round-table discussion of the subject, "New Ideas in Petroleum Exploration," was held on the afternoon of April 10. Following was the program.

A. I. Levorsen: "Petroleum Geology"
P. E. Fitzgerald: "Chemical Engineering in Petroleum Exploration and Production"
C. V. Millikan: "Petroleum Engineering as an Aid in Exploration Geology"
E. A. Eckhardt: "Geophysics"
E. E. Rosaire: "Geochemical Prospecting for Petroleum"
F. H. Lahee: "Where Will Young Graduates in Petroleum Geology Acquire Field Experience"
E. DeGolyer: "Future Position of Petroleum Geology in the Oil Industry"

The results of the two symposia in Chicago were published in the August issue of the *Bulletin.*

The subject for the round-table discussion to be held this evening is: "Possible Future Oil Provinces of the United States and Canada." The material to be presented is a result of work by fifty or more members of the Association, and it is hoped it will prove a stimulating experience to all who attend.

A. I. LEVORSEN, *chairman*

EXHIBIT VII. REPORT OF REPRESENTATIVE ON DIVISION OF GEOLOGY AND GEOGRAPHY OF NATIONAL RESEARCH COUNCIL, 1940–1941

Since the meetings of the Division of Geology and Geography of the National Research Council are held in the latter part of April or the first of May, the first meeting at which I shall attend will be May 3, 1941, when I shall attend as official representative of the Association. My report this year, therefore, will consist merely of listing the various activities of the Division. The subcommittees of the Division now active are: Basic Geographical Data and Techniques; Coöperation with the Bureau of the Census; Density Currents; Geographical Studies of Mineral Distribution; the Measurement of Geologic Time; Micropaleontology; Paleobotany; Research in Areas of International Concern; Research in the Earth Sciences; Sedimentation; Stratigraphy; Tectonics; Glacial Map of North America; Coöperation with the Soil Survey; Problems of Ore Deposition; Landforms.

During the last few years, twenty-four committee and special reports have been published in mimeographed form. Two of the larger reports are the following.

Report of the Committee on Sedimentation for 1938–39: Parker D. Trask, chairman. September, 1939. 102 pages.

Report of the Committee on Measurement of Geologic Time for 1938–39: Alfred C. Lane, chairman; John Putnam Marble, vice-chairman. September, 1939. 114 pages.

The division originally sponsored the Committee on Recent Marine Sediments. The results of this work were published by the Association in 1939 as a symposium edited by Parker D. Trask. In a like manner the subcommittee on the Lead and Zinc Deposits of the Mississippi Valley Region was originally organized by the Division but the report was published by the Geological Society of America.

The chairman of the Division is elected for 3 years, and for the 3 years preceding June, 1940, was Chester R. Longwell, Yale University. The present chairman is Walter H. Bucher, of Columbia University.

Those wishing detailed information in regard to the work of the Division should address their inquiries to the Division of Geology and Geography, National Research Council, 2101 Constitution Avenue, Washington, D. C.

A. I. LEVORSEN, *representative*

EXHIBIT VIII. REPORT OF COMMITTEE ON GEOLOGIC NAMES AND CORRELATIONS

The committee on geologic names and correlations now has its members in most active oil districts and carries on its regular duties in advising individual geologists and groups of geologists regarding the proper use of geologic

names in their districts. During the past year papers have been checked for the editorial department and suggestions given regarding questions of nomenclature.

In addition to this type of work the committee has become more active on larger problems of constructive nature. Two years ago through a subcommittee a study of the Permian was undertaken and recommendations made that have been generally followed. That sub-committee recommended that the Permian be raised from "series" rank to "system"; it is gratifying that subsequently the United States Geological Survey also decided to designate the Permian as a "system" in its publications.

A second sub-committee was created to study the remaining part of the original Carboniferous, that is, the Pennsylvanian and Mississippian, which are still officially considered as series of the Carboniferous system although almost no petroleum geologists use them in that way at this time. The sub-committee on the Carboniferous consists of seven members with M. G. Cheney as chairman. It has studied the Pennsylvanian and Mississippian and made considerable progress but is not yet ready to make any definite recommendations. This sub-committee will be continued indefinitely and has been instructed to publish a progress report in the Association's *Bulletin* so that work can be followed and members can give them the benefit of their advice and criticism.

Since suggestions have been made that a similar review should be made of the Tertiary of the Gulf Coast area, the committee on geologic names and correlations, at its annual meeting in Houston, on April 3, formed a new sub-committee to study the post-Cretaceous stratigraphy of the United States. The chairman and members of this new sub-committee will be appointed as soon as possible. The purpose of this and the other sub-committee has not been to change the present nomenclature unless necessary, or to upset present usage that may be generally satisfactory. The intent is to review the entire nomenclature of the system and, if possible, to simplify and clarify the use of geologic names and correlations. Members of the sub-committee will be appointed from those districts most concerned and it will be expected that the members of the sub-committee will themselves create, or at least coöperate with, groups or committees of the local geological societies. The post-Cretaceous stratigraphy of the Gulf Coast is a big problem and is entitled to considerable study that may continue indefinitely. It is hoped that all local geological societies in Texas, Louisiana, and Mississippi will actively coöperate with the sub-committee and that worthwhile and constructive conclusions can finally be reached.

During the past year several suggestions have been made to change the accepted usage of certain names of rock units. In particular, the word "stage," which is now reserved for the use of glacial geologists, has been suggested as a unit smaller than "series." This was carefully considered by the committee which voted not to make any changes at this time but to reconsider the matter during the coming year.

Since the purpose of the geologic names committee is to help in all questions regarding the use of geologic names, to try to keep out duplications, and to reduce confusion in terms, the members of this committee are instructed to undertake any projects along those lines in their districts. The work does not have to be done by members of the committee on geologic names

and correlations and the end will be attained if the committee members can suggest and direct others to solve their own problems. The geologists of northern Louisiana and southern Arkansas are to be commended for the excellent manner in which they worked out the nomenclature of the Lower Cretaceous and Jurassic formations, many of which do not come to the surface; and more recently they have assisted the Arkansas Geological Survey in publishing a very complete report on these formations which would not have been possible without their wholehearted and generous coöperation. It is urged that local geological societies create their own sub-committees to study problems of nomenclature in their own areas and their relation to adjacent areas.

JOHN G. BARTRAM, *chairman*

EXHIBIT IX. REPORT OF COMMITTEE FOR PUBLICATION

With the close of this convention, the committee for publication will have completed 4 years of activity for the Association. This committee was organized in 1937 and was given its start by Dr. F. H. Lahee, who was its first chairman.

The purpose of the committee is to aid the editor in the solicitation of manuscripts for publication in the *Bulletin*. Its twenty-four members have interviewed or written to many prospective authors and numerous worthwhile contributions have been obtained in this manner for publication.

The healthy condition of the *Bulletin* during the last year will attest somewhat to the value of this committee. A plentiful supply of papers has been on hand at all times. It should be pointed out, however, that the energy and resourcefulness of the editor, Dr. Ver Wiebe, have been the main factors in making the *Bulletin* the fine publication that it is.

It may be of interest to you to know the geographic distribution of the various members of the committee. They are located over the United States as follows: Amarillo, Dallas, Fort Worth, Houston, Midland, San Antonio, and Sinton, Texas; Wichita, Kansas; Oklahoma City and Tulsa, Oklahoma; Urbana, Illinois; Charleston, West Virginia; Ashland, Kentucky; Shreveport and Lake Charles, Louisiana; Denver, Colorado; Billings, Montana; and Los Angeles and San Francisco, California.

This gives the committee a wide distribution and representatives in or near most of the active oil districts of the United States.

During the past year the committee has, of course, been on the lookout for any good material for publication, but has especially urged members to prepare articles bringing up to date our knowledge of important fields or regions on which papers were printed years ago, but concerning which there is now a great deal of new and corrective information. We have also urged the publication of short geological notes to cover any current topic, but most important, to give data concerning the discovery of new fields. These notes are interesting as news items and are invaluable for reference at future dates. Especially interesting to geologists in the active search for oil is a clear statement of the factors which led to the discovery of the new field.

In conclusion, it is recommended that this committee continue along the same lines as in the past, coöperating closely with the editor and aiding him in his task to turn out an interesting and authoritative *Bulletin*.

ROBERT E. RETTGER, *chairman*

Exhibit X. Report of Resolutions Committee

Be it resolved, That we, the members of the American Association of Petroleum Geologists, express our appreciation and sincere thanks to the following.

The Houston Geological Society, its president, Geo. S. Buchanan, its other officers, and its members

The convention committee, Alexander Deussen, general chairman, and to the following members of his committee

Olin G. Bell, hotel and registration
Paul Weaver, exhibits
Perry Olcott, technical program
W. A. Clark, Jr., research laboratory tours
Paul B. Leavenworth, technical equipment
Wayne F. Bowman, invitations
J. A. Culbertson, field trips
Ben C. Belt, finance
George Sawtelle, entertainment
C. D. Lockwood, publicity and pamphlet
Carleton D. Speed, Jr., reception
K. H. Crandall, transportation
Al Ferrando, golf

To all others who contributed to the success of the twenty-sixth annual meeting of the Association and particularly to the following.

The Kiwanis Club of Houston for their coöperation in relinquishing their luncheon date to facilitate the arrangements for the meeting

Postal Telegraph Company for furnishing and servicing the bulletin boards showing registrations

Western Union for helpful services

The River Oaks Garden Club for arranging the garden tours

The Humble Oil and Refining Company for placing their marine facilities at the disposal of our members

The Freeport Sulphur Company for courtesies in connection with the field trip to Hoskins Mound

The Dow Chemical Company for their courtesy in opening their plant at Freeport

The United Salt Corporation for their courtesies in connection with the field trip to the Hockley Salt Mine

The Management of the Rice Hotel and the other Houston hotels for their splendid coöperation in handling this our largest convention

The Houston Chamber of Commerce for their helpful services

The Houston Chronicle, *The Houston Post*, and *The Houston Press*, and the other newspapers outside of Houston for their excellent publicity in connection with our convention.

The Underwood-Elliott-Fisher Company for their generous loan of equipment

Sakowitz Brothers for arranging the style show

Hughes Tool Company for their free luncheon in connection with the tour of their plant

And to the other companies who opened their laboratories for inspection during this convention.

BE IT FURTHER RESOLVED, That the sincere thanks of the Association be extended to the following distinguished gentlemen who favored us with their most excellent addresses.

Robert E. Wilson
J. Edgar Pew
N. C. McGowen
Sumner T. Pike

And the following whose contributions assured the success of this convention.

Dowell, Inc.
General Crude Oil Company
Walter L. Goldston
Gulf Oil Corporation
Halliburton Oil Well Cementing Company
Houston Oil Company of Texas
Humble Oil and Refining Company
Kirby Petroleum Company
Lane-Wells Company
Ohio Oil Company
Phillips Petroleum Company
Pure Oil Company
Schlumberger Well Surveying Corporation
Shell Oil Company, Inc.
Standard Oil Company of California
Standard Oil Company of Kansas
The Texas Company
Texas Gulf Producing Company
Texas Gulf Sulphur Company
Tide Water Associated Oil Company
Union Oil Company of California
Union Producing Company

BE IT FURTHER RESOLVED, That the sincere thanks of the Association be given to the executive committee for the efficient and able manner in which they have conducted the affairs of the Association during the past year.

BE IT FURTHER RESOLVED, That our thanks and appreciation be given to the Society of Economic Paleontologists and Mineralogists, its president, Carey Croneis, its other officers and its members; and the Society of Exploration Geophysicists, its president, W. T. Born, its other officers, and its members for their splendid coöperation.

BE IT FURTHER RESOLVED, That these resolutions be inscribed in the minutes of this meeting and that the secretary be instructed to forward copies to all those individuals, organizations and companies herein named.

A. R. DENISON, *chairman* C. R. MCCOLLOM J. R. LOCKETT

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 25, NO. 5 (MAY, 1941), PP. 982-990

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

CONSTITUTION AND BY-LAWS

(Adopted 1918, and amended 1921, 1922, 1923, 1925, 1927, 1928, 1929, 1930, 1932, 1933, 1935, 1936, 1939, and 1940)

CONSTITUTION

ARTICLE I. NAME

This Association shall be called "The American Association of Petroleum Geologists," incorporated under the laws of Colorado the 21st day of April, 1924, for a period of twenty (20) years.

ARTICLE II. OBJECT

The object of this Association is to promote the science of geology, especially as it relates to petroleum and natural gas; to promote the technology of petroleum and natural gas and to encourage improvements in the methods of exploring for and exploiting these substances; to foster the spirit of scientific research amongst its members; to disseminate facts relating to the geology and technology of petroleum and natural gas; to maintain a high standard of professional conduct on the part of its members; and to protect the public from the work of inadequately trained and unscrupulous persons posing as petroleum geologists.

ARTICLE III. MEMBERSHIP

Members

SECTION 1. Any person engaged in the work of petroleum geology or in research pertaining to petroleum geology or technology is eligible to active membership, provided he is a graduate of an institution of collegiate standing, in which institution he has done his major work in geology, or in sciences fundamental to petroleum geology, and in addition has had the equivalent of three years' experience in petroleum geology or in the application of these other sciences to petroleum geology or to research in petroleum geology or technology; and provided further that in the case of an applicant for membership who has not had the required collegiate or university training, but whose standing in the profession is well recognized, he shall be admitted to membership when his application shall have been favorably and unanimously acted upon by the executive committee; and provided further that these requirements shall not be construed to exclude teachers and research workers in recognized institutions, whose work is of such character as in the opinion of the executive committee shall qualify them for membership.

Active members alone shall be known as members.

Life Members

SECTION 2. The executive committee may grant life membership to members who have paid their dues and are otherwise qualified.

Associates

SECTION 3. Any person having completed as much as thirty hours of geology (an hour shall here be interpreted as meaning as much as sixteen recitation or lecture periods of one hour each, or the equivalent in laboratory) in a reputable institution of collegiate or university standing, or who has done field work equivalent to this, is eligible to associate membership, provided at the time of his application for membership he shall be engaged in geological studies in an institution of collegiate or university standing, or shall be engaged in petroleum geology; and any person who is a graduate of an institution of collegiate standing in which he has done his major work in sciences fundamental to petroleum geology or petroleum technology, and who has the equivalent of one year's experience in the application of his science to the study of petroleum geology, shall be eligible to associate membership, provided at the time of his application for membership he shall be engaged in investigations in the broader subject of petroleum geology and technology.

Associate members shall be known as associates.

Associates shall enjoy all the privileges of membership in the Association, save that they shall not hold office, sign applications for membership, or vote; neither shall they have the privilege of advertising their affiliation with the Association in professional cards or professional reports or otherwise.

The executive committee may advance to active membership, without the formality of application for such change, those associates who have, subsequent to election, fulfilled the requirements for active membership.

Election to Membership

SECTION 4. Every candidate for admission as a member or associate shall submit a formal application on an application form authorized by the executive committee, signed by him, and endorsed by not less than three members who are in good standing, stating his training and experience and such other facts as the executive committee shall from time to time prescribe. Provided the executive committee, after due consideration, shall judge that the applicant's qualifications meet the requirements of the constitution, they shall cause to be published in the *Bulletin* the applicant's name and the names of his sponsors. If, after at least thirty days have elapsed since such publication, no reason is presented why the applicant should be not admitted, he shall be deemed eligible to membership or to associate membership, as the case may be, and shall be notified of his election.

SECTION 5. An applicant for membership, on being notified of his election in writing, shall pay full membership dues for the current year and on making such payment shall be entitled to receive the entire *Bulletin* for that year. Unless payment of dues is made within thirty (30) days by those living within the continental United States and within ninety (90) days by those living elsewhere, after notice of election has been mailed, the executive committee may rescind the election of the applicant. Upon payment of dues, each applicant for membership shall be furnished with a membership card for the current year, and until such written notice and card are received, he shall in no way be considered a member of the Association.

Honorary Members

SECTION 6. The executive committee may from time to time elect as hon-

orary members persons who have contributed distinguished service to the cause of petroleum geology. Honorary members shall not be required to pay dues.

ARTICLE IV. OFFICERS AND THEIR DUTIES

Officers

SECTION 1. The officers of the Association shall be a president, a vice-president, a secretary-treasurer, and an editor. These, together with the past president, shall constitute the executive committee and managers of the Association.

SECTION 2. The officers shall be elected annually from the Association at large by written ballot deposited in a locked ballot box by those members, present at the annual meeting, who have paid their current dues and are otherwise qualified under the constitution. Each candidate, when voted for as a candidate for the particular office for which he is nominated, shall be thereby automatically voted for as a candidate for the executive committee for one year, except that candidates for the presidency shall be automatically voted for as candidate for the executive committee for two years.

SECTION 3. No one shall hold the office of president for two consecutive years and no one shall hold any other office for more than two consecutive years except the editor who shall not hold office for more than six consecutive years.

Duties of Officers

SECTION 4. The president shall be the presiding officer at all meetings of the Association, shall take cognizance of the acts of the Association and of its officers, shall appoint such committees as are required for the purposes of the Association, and shall delegate members to represent the Association. He may, at his option, serve on, and may be chairman of, any committee.

SECTION 5. The vice-president shall assume the office of president in case of a vacancy from any cause in that office and shall assume the duties of president in case of the absence or disability of the latter. If the past-president shall for any reason be unable to serve as a member of the executive committee, the president shall fill the vacancy by the appointment of the next available preceding past-president.

A vacancy or disability occurring in the office of vice-president, secretary-treasurer, or editor shall be filled by majority vote of the executive committee, either for the unexpired term or for the period of disability, as the committee may decide. In the case of a tie, the president shall cast the deciding vote.

SECTION 6. The secretary-treasurer shall assume the duties of president in case of the absence of both the president and vice-president. He shall have charge of the financial affairs of the Association and shall annually submit reports as secretary-treasurer covering the fiscal year. He shall receive all funds of the Association, and, under the direction of the executive committee, shall disburse all funds of the Association. He shall cause an audit to be prepared annually by a public accountant at the expense of the Association. He shall give a bond, and shall cause to be bonded all employees to whom authority may be delegated to handle Association funds. The amount of such bonds shall be set by the executive committee and the expense shall be borne by

the Association. The funds of the Association shall be disbursed by check as authorized by the executive committee.

SECTION 7. The editor shall be in charge of editorial business, shall submit an annual report of such business, shall have authority to solicit papers and material for the *Bulletin* and for special publications, and, with the approval of the executive committee, may accept or reject material offered for publication. He may appoint associate, regional, and special editors.

SECTION 8. The officers shall assume the duties of their respective offices immediately after the annual meeting in which they are elected.

ARTICLE V. EXECUTIVE COMMITTEE—MEETINGS AND DUTIES

Executive Committee

SECTION 1. The executive committee shall consist of the president, past-president, vice-president, secretary-treasurer, and editor.

Meetings and Duties

SECTION 2. The executive committee shall meet immediately preceding the annual meeting and at the call of the president may hold meetings when and where thought advisable, to conduct the affairs of the Association. A joint meeting of the outgoing and incoming executive committees shall be held immediately after the close of the annual Association business meeting. Members of the executive committee may vote by proxy on matters which require a unanimous vote.

SECTION 3. The executive committee shall consider all nominations for membership and pass on the qualifications of the applicants; shall have control and management of the affairs and funds of the Association; shall determine the manner of publication and pass on the material presented for publication; and shall designate the place of the annual meeting. They are empowered to establish a business headquarters for the Association, and to employ such persons as are needed to conduct the business of the Association. They are empowered to accept, create, and maintain special funds for publication, research, and other purposes. They are empowered to make investments of both general and special funds of the Association. Trust funds may be created, giving to the trustees appointed for such purpose, such direction as to investments as seems desirable to the executive committee to accomplish any of its objects and purposes, but no such trust funds shall be created unless they are revocable upon ninety (90) days' notice.

ARTICLE VI. MEETINGS

The Association shall hold at least one stated meeting each year, which shall be the annual meeting. This meeting shall be held in March or April at a time and place designated by the executive committee. At this meeting the election of members shall be announced, the proceedings of the preceding meeting shall be read, Association business shall be transacted, scientific papers shall be read and discussed and officers for the ensuing year shall be elected.

ARTICLE VII. AMENDMENTS

Amendments to this constitution may be proposed by a resolution of the executive committee, by a constitutional committee appointed by the presi-

dent, or in writing by any ten members of the Association. All such resolutions or proposals must be submitted at the annual meeting of the business committee of the Association as provided in the by-laws, and only the business committee shall make recommendations concerning proposed constitutional changes at the annual Association business meeting. If such recommendations by the business committee shall be favorably acted on at the annual Association business meeting, the secretary-treasurer shall arrange for a ballot of the membership by mail within thirty (30) days after said annual Association business meeting, and a majority vote of the ballots received within ninety (90) days of their mailing shall be sufficient to amend. The legality of all amendments must be determined by the executive committee prior to balloting.

BY-LAWS

ARTICLE I. DUES

SECTION 1. The fiscal year of the Association shall correspond with the calendar year.

SECTION 2. The annual dues of members of the Association shall be ten dollars ($10.00). The annual dues of associates for not to exceed three years after election shall be six dollars ($6.00); for the second three-year period eight dollars ($8.00); thereafter, the annual dues of such associates shall be ten dollars ($10.00). The annual dues are payable in advance on the first day of each calendar year. A bill shall be mailed to each member and associate before January first of each year, stating the amount of the annual dues and the penalty and conditions for default in payment. Members or associates who shall fail to pay their annual dues by April first shall not receive copies of the April *Bulletin* or succeeding *Bulletins*, nor shall they be privileged to buy Association special publications at prices made to the membership, until such arrears are met.

SECTION 3. On the payment of two hundred dollars ($200.00) any member in good standing shall be declared a life member and thereafter shall not be required to pay annual dues. The funds derived from this source shall be placed in a permanent investment, the income from which shall be devoted to the same purposes as the regular dues.

ARTICLE II. RESIGNATION—SUSPENSION—EXPULSION

SECTION 1. Any member or associate may resign from the Association at any time. Such resignation shall be in writing and shall be accepted by the executive committee, subject to the payment of all outstanding dues and obligations of the resigning member or associate.

SECTION 2. Any member or associate who is more than a year delinquent (in arrears) in payment of dues shall be suspended from the Association. Any delinquent or suspended member or associate, at his own option, may request in writing that he be dropped from the Association and such request shall be granted by the executive committee. Any member or associate more than two years in arrears shall be dropped from the Association. The time of payment of delinquent dues for either one year or two years may be extended by unanimous vote of the executive committee.

SECTION 3. Any member or associate who resigns or is dropped under the

provisions of Sections 1 and 2 of this article ceases to have any rights in the Association and ceases to incur further indebtedness to the Association.

SECTION 4. Any person who has ceased to be a member or associate under Section 1 or Section 2 of this article may be reinstated by unanimous vote of the executive committee subject to the payment of any outstanding dues and obligations which were incurred, prior to the date when he ceased to be a member or associate of the Association.

In the case of any member or associate who has been dropped between the dates of January 1, 1931, and January 1, 1936, for non-payment of dues and who shall apply for reinstatement, the executive committee is authorized, at its discretion, to accept the resignation of such member or associate effective at any date during such period of delinquency, provided, the member shall pay all indebtedness to the Association incurred prior to the date of such resignation including a proper proportion of annual dues as shall be fixed by the executive committee. Such member or associate shall not be entitled to receive the *Bulletin* for any period subsequent to the date when his resignation became effective and prior to his reinstatement.

SECTION 5. Any member or associate who, after being granted a hearing by the executive committee, shall be found guilty of a violation of the code of ethics of this Association or shall be found guilty of a violation of the established principles of professional ethics, or shall be found guilty of having made a false or misleading statement in his application for membership in the Association, may be suspended or expelled from the Association by unanimous vote of the executive committee. The decision of the executive committee in all matters pertaining to the interpretation and execution of the provisons of this section shall be final.

ARTICLE III. PUBLICATIONS

SECTION 1. The proceedings of the annual meeting and the papers presented at such meeting shall be published at the discretion of the executive committee in the Association *Bulletin* or in such other form as the executive committee may decide best meets the needs of the membership of the Association.

SECTION 2. The payment of annual dues for any fiscal year entitles the member or associate to receive without further charge a copy of the *Bulletin* of the Association for that year.

SECTION 3. The executive committee may authorize the printing of special publications to be financed by the Association from its general, publication, or special funds and offered for sale to members and associates in good standing at not less than cost of publication and distribution.

ARTICLE IV. REGIONAL SECTIONS, TECHNICAL DIVISIONS, AND AFFILIATED SOCIETIES

SECTION 1. Regional sections of the Association may be established provided the members of such sections are members of the Association and shall perfect an organization and make application to the executive committee. The executive committee shall submit the application to a vote at a regular annual meeting, an affirmative vote of two-thirds of the members present and voting being necessary for the establishment of such a section; and provided that the Association may revoke the charter of any regional section

by a vote of two-thirds of the members present and voting at a regular annual meeting.

SECTION 2. Technical divisions may be established, provided the members interested shall perfect an organization and make application to the executive committee. The executive committee shall submit the application to a vote at a regular meeting, an affirmative vote of two-thirds of the membership present and voting being necessary for the establishment of such a division. In like manner, the Association may dissolve a division by an affirmative vote of two-thirds of the members present and voting at any annual meeting. A technical division may have its own officers, and it may have its own constitution and by-laws provided that, in the opinion of the executive committee, these do not conflict with the constitution and by-laws of the Association. The executive committee shall be empowered to make arrangements with the officers of the division for the conduct of the business of the division. A division may admit to affiliate membership in the division specially qualified persons who are not eligible to membership in the Association. Technical divisions may affiliate with other scientific societies, with the approval of the executive committee.

SECTION 3. Subject to the affirmative vote of two-thirds of the membership present and voting at an annual meeting, and with legal advice, the executive committee may arrange for the affiliation with the Association of duly organized groups or societies, which by objects, aims, constitution, by-laws, or practice are developing the study of geology or petroleum technology. In like manner and with like advice, the executive committee may arrange conditions for dissolution of such affiliations. Affiliation with the Association need not prevent affiliation with other scientific societies. Members of affiliated societies who are not members of the Association, shall not have the privilege of advertising their affiliation with the Association on professional cards or otherwise.

ARTICLE V. DISTRICT REPRESENTATIVES

The executive committee shall cause to be elected district representatives from districts which it shall define by a local geographic grouping of the membership. Such districts shall be redesignated and redefined by the executive committee as often as seems advisable. Each district shall be entitled to one representative for each seventy-five members, but this shall not deprive any designated district of at least one representative. The representatives so apportioned shall be chosen from the membership of the district by a written ballot arranged by the executive committee. They shall hold office for two years, their term of office expiring at the close of the annual meeting.

ARTICLE VI. COMMITTEES

Appointment and Tenure

SECTION 1. There shall be the following standing committees:

Business Committee
Research Committee
Committee on Geologic Names and Correlations
Committee on Applications of Geology
Committee for Publication

Finance Committee
Trustees of Revolving Publication Fund
Trustees of Research Fund

The president shall appoint all standing committees except the business committee for which provision is hereafter made. Members of all committees except the business committee shall serve for a three-year term, but in rotation, with one-third of the members being appointed each year. The president shall designate the chairmen, annually, shall have power to fill vacancies, and shall notify the members of the committees of their appointment. The president may designate one or more vice-chairmen annually.

In addition to the aforesaid standing committees, the president shall appoint annually or semiannually a resolutions committee, and such special committees as the executive committee may authorize. Special committees shall be appointed for a term of one year. The president shall designate the chairmen of such committees.

Business Committee

SECTION 2. The business committee shall act as a council and advisory board to the executive committee and the Association. This committee shall consist of the executive committee, not more than five members at large appointed annually by the president, two members elected by and from each technical division, and the district representatives. The president shall also appoint annually a chairman and a vice-chairman, but neither of these need be one of those otherwise constituting the business committee. The secretary-treasurer shall act as secretary of the business committee. If a district or technical representative is unable to be present at any meeting of the committee he may designate an alternate, who, in the case of a district representative, may or may not be a resident of the district he is asked to represent, and the alternate, on presentation of such a designation in writing, shall have the same powers and privileges as a regularly chosen representative. The business committee shall meet the day before the annual meeting at which all proposed changes in the constitution or by-laws shall be considered, all old and new business shall be discussed, and recommendations shall be voted for presentation at the annual meeting.

Research Committee

SECTION 3. The purpose of the research committee is the advancement of research, particularly within the field of petroleum geology. The committee shall consist of twenty-four members unless a different number is authorized by the executive committee.

Committee on Geologic Names and Correlations

SECTION 4. The purpose of the committee on geologic names and correlations is to lend assistance to authors on problems of stratigraphy and nomenclature and to advise the editor and executive committee in regard to the propriety of the use of stratigraphic names and correlations in papers submitted for publication by the Association. The committee shall consist of fifteen members unless a different number is authorized by the executive committee.

Committee on Applications of Geology

SECTION 5. The object of the committee on applications of geology is to advise and promote ways and means for informing the general public on all phases of geology, particularly on the natural occurrence of oil and gas underground, the methods of searching for these substances, and the methods of exploiting them. The committee shall consist of twelve members unless a different number is authorized by the executive committee.

Committee for Publication

SECTION 6. The purpose of the committee for publication is to assist in securing desirable manuscripts for publication in the *Bulletin* or other publications of the Association. The committee may also assist in securing papers for delivery at the annual meetings. The committee shall consist of twenty-four members unless a different number is authorized by the executive committee.

Finance Committee

SECTION 7. The finance committee shall act as financial advisers to the executive committee. The committee shall consist of three members. If a member of the finance committee should be elected to the executive committee he shall resign from the finance committee and the president shall appoint a member of the Association to complete his unexpired term.

Trustees of Revolving Publication Fund

SECTION 8. Before any publication project shall be undertaken with the use of the revolving publication fund the approval of the trustees and the executive committee must be secured. There shall be three trustees. If a trustee should be elected to the executive committee he shall resign as a trustee and the president shall appoint a member of the Association to complete his unexpired term.

Trustees of Research Fund

SECTION 9. Before any research work may be undertaken with the use of money from the research fund, the approval of the trustees and the executive committee shall be secured. There shall be three trustees. If a trustee shall be elected to the executive committee he shall resign as a trustee and the president shall appoint a member of the Association to complete his unexpired term.

Resolutions Committee

SECTION 10. The resolutions committee shall be charged with the duty of presenting at the annual and semi-annual meetings resolutions expressing the Association's appreciation and thanks to those who have worked and contributed to the success of the meetings.

ARTICLE VII. AMENDMENTS

These by-laws may be amended by vote of three-fourths of the members present and voting at any annual meeting, provided that such changes shall have been recommended to the meeting by the business committee and provided that their legality shall be determined by the executive committee prior to publication.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 25, NO. 5 (MAY, 1941), PP. 991–995, 1 FIG.

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

HARRY L. THOMSEN, of the Shell Oil Company, Inc., has moved from Los Angeles to Bakersfield, California.

C. EDWIN MOHLER, of the Carter Oil Company, has moved from Norman, Oklahoma, to Mattoon, Illinois.

A. P. LOSKAMP, recently with the Barnsdall Oil Company at Midland, is now with the Union Oil Company of California, 1214 Petroleum Building, Midland, Texas.

STEWART CRONIN, of the Pure Oil Company, has moved from Olney, Illinois, to Tulsa, Oklahoma.

CLARK MILLISON and W. B. MILLISON announce their association as the Oil Investment Company for consulting, purchasing, selling oil leases and royalties, with offices in the Beacon Building, Tulsa, Oklahoma.

HERBERT YOHO, recently at Byesville, Ohio, has moved to Clayton, Georgia, where he is assistant supervisor on the State Mineral Survey.

The South Louisiana Geological Society, Lake Charles, Louisiana, on March 18, listened to H. E. MCGLASSON, of the Stanolind Oil and Gas Company, give a paper on "The Geology of South Jennings Field, Jefferson Davis Parish, Louisiana, with Special Reference to the Contemplated Recycling Project."

WALLACE E. PRATT, a past-president of the Association, a director of the Standard Oil Company of New Jersey, and an alumnus of the University of Kansas, lectured before the students and faculty of the departments of geology and petroleum engineering of the University of Kansas, in March, on "Oil in the Earth," "Where Oil Is," "Who Finds Oil—and How," and "Oil and Human Culture."

LOUISE JORDAN, geologist with Anzac Oil Corporation, Coleman, Texas, has resigned to join the Sun Oil Company as paleontologist in the Dallas office.

HERMAN GUNTER, State geologist of Florida, recently talked before the Mississippi Geological Society at Jackson, Mississippi, on the "Stratigraphy and Structure of Florida."

Lieutenant Colonel BYRON RIFE is at the Baytown Ordnance Works, Baytown, Texas.

TOM M. GIRDLER, JR., may be addressed in care of The Texas Company, Box 1270, Midland, Texas.

P. E. FITZGERALD talked on "Modern Methods of Field Sample Testing to Improve Acidizing," before the Tulsa Geological Society, April 7.

W. C. KRUMBEIN, of the University of Chicago, was awarded a Guggenheim Fellowship of $2,500 to undertake a year's research in applications of fluid mechanics to sedimentary problems. He will be given a leave of absence from the University, and will divide his time between the Iowa Institute of Hydraulic Research and the University of California at Berkeley. The specific wording of the grant is "a study of the dynamical processes by which sedimentary particles are abraded, changed in shape, and sorted into the deposits found in nature." It is expected that this study will furnish criteria for the better interpretation of the history of ancient sediments.

JUDSON S. SWEARINGEN, of the department of chemical engineering at the University of Texas, on March 24 discussed recycling processes at an open meeting of the East Texas Geological Society.

S. F. SHAW, of San Antonio, addressed the Student Chapter of the A.I.M.E., University of Texas, on March 27, on the subject of "Principles of the Air-Gas Lift."

RALPH S. COOLEY, for the past 5 years in charge of the West Texas-New Mexico district for The Sloan and Zook Company of Bradford, Pennsylvania, has resigned his position with that company and has opened an office in the First National Bank Building in Midland, Texas, for George P. Livermore, Inc. Cooley will devote most of his time to exploration activities.

The Fifth Conference of Field Men of the Mineral Classification Division, the Mining Division, and the Oil and Gas Leasing Division of the Conservation Branch of the Geological Survey of the United States Department of the Interior was held at the Mayo Hotel, Tulsa, Oklahoma, from March 27 through April 2.

PAUL B. HUNTER, of the Shell Oil Company, Inc., Houston, Texas, has resigned his company position, after 12 years association with the Shell. He will engage in independent work.

S. RUSSELL CASEY, of the Woodley Petroleum Company, and RALPH B. CANTRELL, of the Lane-Wells Company, of Houston, recently talked before the Houston Geological Society on the "Davis Sand Lens of the Hardin Field, Liberty County, Texas."

J. A. MULL, of the Republic Natural Gas Company, Wichita, Kansas, spoke before the Dallas Petroleum Geologists, March 25, on "Stream Channels Applied to the Arbuckle of Central Kansas Uplift."

GEOFFREY BARROW has left the Island Exploration Company, Ltd. and is with the Papuan Apinaipi Petroleum Company, Ltd., Oiapu, G. D., Papua.

The Appalachian Geological Society, Box 1435, Charleston, West Virginia, has published a *Table of Open-Flow Capacities of Gas Wells*. The flow is calculated for pipe of various sizes.

L. EDWIN PATTERSON, JR., for the last 3 years district geologist for the Cities Service Oil Company at Wichita Falls, Texas, has been ordered for a year of active duty as a captain of field artillery with the 26th Field Artillery Brigade at Camp Roberts, California.

W. TAPPOLET, recently with the Caribbean Petroleum Company, Maracaibo, Venezuela, is with the Shell Oil Company, Inc., Los Angeles, California.

A. I. LEVORSEN gave a series of three lectures on petroleum geology before the geological department of the University of Missouri at Columbia, Missouri, April 21–23.

W. D. CHAWNER is with the Carter Oil Company, Standard of Louisiana Building, Shreveport, Louisiana.

The annual convention of the National Oil Scouts and Landmen's Association will be held in Dallas, Texas, on May 29, 30, and 31, at the Adolphus Hotel as general headquarters.

At the last meeting of the season, the Rocky Mountain Association of Petroleum Geologists, Denver, Colorado, April 21, discussed "Possible Future Oil-Producing Areas in the Rocky Mountain Region."

The Tulsa Geological Society held a symposium on "Occurrence of Oil and Gas in Northeast Central Oklahoma and Eastern Kansas, April 21, led by LUTHER E. KENNEDY, EDMOND O. MARKHAM, T. E. WEIRICH, and others.

DEAN F. METTS, of the Humble Oil and Refining Company, has been transferred from production geology at Crowley to the division office at Lake Charles, working under J. B. CARSEY, division geologist.

The department of geology of the Massachusetts Institute of Technology sponsored the appearance of JOSEPH A. SHARPE, chief geophysicist of the joint geophysical laboratory of the Stanolind Oil and Gas Company and Western Geophysical Company of Tulsa, Oklahoma, in three lectures on geophysical exploration which were given at the Institute, March 10–12.

RAY E. MORGAN has received the degree of M.S. from the University of Minnesota and is teaching geology this spring at the South Dakota State College, Brookings, South Dakota.

HAROLD E. REDMON resigned as superintendent of exploration for The National Refining Company, Cleveland, Ohio, March 31, to accept the management of General Exploration Inc., 208 Miller Theatre Building, Wichita, Kansas. He has been elected secretary-treasurer of General Exploration, which has been retained by the National Refining Company in a consulting capacity.

LEONARD F. UHRIG, of the Shell Oil Company, Inc., is a lieutenant in the 20th Ordnance Battalion, Pine Camp, New York.

F. B. PLUMMER, of the University of Texas, talked on "New Light on the Geology and Structure of the Llano Uplift of Central Texas," before the West Texas Geological Society at Midland, April 18.

ALEXANDER DEUSSEN, consulting geologist, the second president of the A.A.P.G., has been elected honorary life member of the Houston Geological Society.

C. B. ROACH, geologist with the Shell Oil Company, Inc., talked before

the South Louisiana Geological Society at Lake Charles, April 15, on the subject, "Subsurface Study of Jennings Dome, Acadia Parish, Louisiana."

L. F. McCollum, executive vice-president since January 1, 1930, and manager of the exploration department since May 1, 1934, has been promoted to be the president of the Carter Oil Company, Tulsa, Oklahoma.

Harold F. Moses, chief geologist of the Carter Oil Company, Tulsa, has been made head of the exploration department.

Ray A. Hancock, of the Lane-Wells Company, Los Angeles, has been commissioned an ensign in the Naval Communication Reserve, at the Radio and Signal School in Los Angeles.

Watson Caldwell, of the Stanolind Oil and Gas Company, Houston, Texas, recently discussed "The Geology of the West Beaumont Field" before the Houston Geological Society.

C. E. Dobbin, of the United States Geological Survey, Denver, Colorado, spoke before the Oklahoma City Geological Society, early in April, on "Economic Importance of Minerals in Present World Affairs."

The Houston Geological Society has a supply of pamphlets used in connection with the field trips of the 26th annual meeting of the Association, April 1–5. *An Introduction to Gulf Coast Geology* contains a regional map on the *Heterostegina* of the Houston area of the Gulf Coast, and structural maps of all types of fields on the Gulf Coast. The *Guide for Field Trips* contains maps of nine fields in the Houston area. They are priced at 50¢ each to A.A.P.G. members and $1.00 to nonmembers, and may be obtained from Leslie Bowling, secretary of the Houston Geological Society, at 1134 Commerce Building, Houston, Texas.

Charles H. Behre, Jr., formerly professor of economic geology at Northwestern University, has been appointed professor of economic geology at Columbia University.

Henry Carter Rea has left the Seaboard Oil Company and may be addressed at 4035 North State Street, Jackson, Mississippi.

H. E. Rothrock, who as assistant chief of the Naturalist Division is in charge of geologic work in the National Park Service areas, has recently returned from the Virgin Islands. The purpose of the trip was to implement the drilling program which has been undertaken for the purpose of supplying Government projects with water. Twenty-two wells will be drilled with a light rotary machine operated by the Civilian Conservation Corps.

Frank S. Hudson has resigned from the Shell Oil Company, Inc., after fifteen years of service in various positions in its geological and production departments. He has made no announcement of plans for future activities. His present address is 138 North Norton Avenue, Los Angeles.

Photograph taken at luncheon given by Dr. G. Zuloaga in honor of Dr. Hollis D. Hedberg, at the Caracas Country Club, Caracas, Venezuela, March 27, 1941, on the occasion of the granting of the "Medalla de Honor de Instrucción Pública" to Dr. Hedberg and Dr. L. Kehrer, by the Venezuelan Government. Dr. Kehrer, of Ecuador, was not present. Sitting, from left to right: Dr. G. Zuloaga, Dr. F. Corrigan, American Ambassador to Venezuela; Dr. Hollis D. Hedberg, Dr. Arturo Uslar Pietri, Minister of National Education; Chester M. Crebbs. Standing, first row: Dr. H. Stauffer, Dr. Manuel Tello B., Dr. Clemente Gonzalez de Juana, Dr. Hans Kugler, Pedro I. Aguerreverre, Dr. Ely Mencher, C. E. Hobley, Chester Baird. Second row: Carlos Freeman, Joseph A. Holmes, P. E. Nolan, Aden E. Stiles, L. T. Hart.

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VOL. 25, NO. 5 (MAY, 1941), P. 996

FIELD TRIP

OKLAHOMA CITY GEOLOGICAL SOCIETY, MAY 30, 31, JUNE 1

The Oklahoma City Geological Society will hold its annual field trip, May 30, 31, and June 1, to study the Mesozoic rocks of the Oklahoma Panhandle and an adjacent area in New Mexico. J. Willis Stovall, of the department of geology of the University of Oklahoma, will lead the party. Registration will be at the Crystal Hotel in Boise City on Thursday evening, May 29. At 7:00 o'clock there will be a banquet in the Legion Hall after which Dr. Stovall will give an illustrated lecture, using color slides to review the things that will be seen during the next three days.

Friday, May 30, will be spent around Battle Ship Mound in New Mexico. The party will return to Boise City that night.

On Saturday, May 31, the party will work in the Black Mesa and Cimarron Canyon area and at Red Point. That night will be spent in Liberal, Kansas, where there will be another dinner meeting. After the dinner there will be a discussion on the Hugoton-Guyman-Amarillo gas area of Kansas, Oklahoma, and Texas.

On Sunday, June 1, the party will work south of Liberal and then back toward the east with the trip breaking up about noon.

Committee members are as follows.

Lester L. Whiting, general chairman
Charles N. Gould
Irving Perrine
John Sanford
Hubert E. Bale
I. Curtis Hicks
Ralph Fillmore
Graydon H. Laughbaum

Persons planning to attend should notify Ralph Fillmore, Anderson-Prichard Oil Company, 1000 Ramsey Tower, Oklahoma City, as soon as possible so that the necessary provisions for meals and hotel accommodations can be made.

PROFESSIONAL DIRECTORY

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J. E. EATON
Consulting Geologist

2062 N. Sycamore Avenue
LOS ANGELES, CALIFORNIA

PAUL P. GOUDKOFF
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Petroleum Geologist

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TULSA OKLAHOMA

G. H. WESTBY
Geologist and Geophysicist
Seismograph Service Corporation

Kennedy Building Tulsa, Oklahoma

PENNSYLVANIA

HUNTLEY & HUNTLEY
Petroleum Geologists
and Engineers

L. G. HUNTLEY
J. R. WYLIE, JR.
Grant Building, Pittsburgh, Pa.

TEXAS

JOSEPH L. ADLER
Geologist and Geophysicist

Consultant and Contractor in Geological and Geophysical Exploration

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DENVER, COLORADO

President - - - - - - - - Ninetta Davis
224 U. S. Customs Building
1st Vice-President - - - - - - - James Boyd
2nd Vice-President - - - - - H. E. Christensen
The Texas Company
Secretary-Treasurer - - - - - Dart Wantland
927 Humboldt Street

Dinner meetings, first and third Mondays of each month, 6:15 P.M., Auditorium Hotel.

ILLINOIS

ILLINOIS GEOLOGICAL SOCIETY

President - - - - - - - - - - L. M. Clark
Shell Oil Company, Inc., Centralia

Vice-President - - - - - - C. B. Anderson
Gulf Refining Company, Mattoon

Secretary-Treasurer - - - - - Robert G. Kurtz
The Ohio Oil Company, Marshall

Meetings will be announced.

KANSAS

KANSAS GEOLOGICAL SOCIETY

WICHITA, KANSAS

President - - - - - - - - John W. Inkster
Shell Oil Company, Inc.
Vice-President - - - - - - - - J. P. McKee
Consulting Geologist
Secretary-Treasurer - - - - - Lee H. Cornell
Stanolind Oil and Gas Company
Manager of Well Log Bureau - Harvel E. White

Regular Meetings: 7:30 P.M., Geological Room, University of Wichita, first Tuesday of each month. Visitors cordially welcomed.

The Society sponsors the Kansas Well Log Bureau which is located at 412 Union National Bank Building.

LOUISIANA

THE SHREVEPORT GEOLOGICAL SOCIETY

SHREVEPORT, LOUISIANA

President - - - - - - - Warren B. Weeks
Phillips Petroleum Co., 1009 Giddens-Lane Bldg.
Vice-President - - - - Weldon E. Cartwright
Tide Water Associated—Seaboard Oil Cos.
Secretary-Treasurer - - - - Van D. Robinson
Atlantic Refining Company, 914 Giddens-Lane Bldg.
Historian - - - - - - - - - Robert B. Totten
Phillips Petroleum Company

Meets the first Friday of every month, 7:30 P.M., Civil Courts Room, Caddo Parish Court House. Special dinner meetings by announcement.

SOUTH LOUISIANA GEOLOGICAL SOCIETY

LAKE CHARLES, LOUISIANA

President - - - - - - - - - W. R. Canada
Stanolind Oil and Gas Company
Vice-President - - - - - - - P. H. Jennings
Magnolia Petroleum Company
Secretary - - - - - - - - - E. M. Baysinger
Box 210
Treasurer - - - - - - - - - Baker Hoskins
Shell Oil Company, Inc., Box 598

Meetings: Luncheon 1st Wednesday at Noon (12:00) and business meeting third Tuesday of each month at 7.00 P.M. at the Majestic Hotel. Visiting geologists are welcome.

MICHIGAN

MICHIGAN GEOLOGICAL SOCIETY

President - - - - - - - - Jed B. Maebius
Gulf Refining Company, Saginaw

Vice-President - - - - - - - Lee C. Lamar
Carter Oil Company, Saginaw

Secretary-Treasurer - - - - - - Justin Zinn
Michigan State College, East Lansing

Business Manager - - - - - - Lee C. Miller
State Proration Officer, Lansing

Meetings: Monthly dinner meetings rotating between Saginaw, Mt. Pleasant, and Lansing. Informal dress.

MISSISSIPPI

MISSISSIPPI GEOLOGICAL SOCIETY
JACKSON, MISSISSIPPI

President - - - - - - - - Urban B. Hughes
Consulting Geologist, 1205 Tower Building
Vice-President - - - - - - Tom McGlothlin
Gulf Refining Company, Box 1105
Secretary-Treasurer - - - - David C. Harrell
Carter Oil Company, Box 1490

Meetings: First and third Wednesdays of each month ,from October to May, inclusive, at 7:30 P.M., Edwards Hotel, Jackson, Mississippi. Visiting geologists welcome to all meetings.

OKLAHOMA

ARDMORE GEOLOGICAL SOCIETY
ARDMORE, OKLAHOMA

President - - - - - - - - C. W. Tomlinson
509 Simpson Building
Vice-President - - - - - - Tom L. Coleman
U. S. Geological Survey, Box 719
Secretary-Treasurer - - - - - - Bob Hancock
Magnolia Petroleum Company, Box 299

Dinner meetings will be held at 7:00 P.M. on the first Wednesday of every month from October to May, inclusive, at the Ardmore Hotel.

OKLAHOMA

OKLAHOMA CITY GEOLOGICAL SOCIETY
OKLAHOMA CITY, OKLAHOMA

President - - - - - - - John E. VanDall
Magnolia Petroleum Company
Vice-President - - - - - - Clyde H. Dorr
Consulting Geologist, 1801 Petroleum Bldg.
Secretary-Treasurer - - Graydon H. Laughbaum
Sinclair Prairie Oil Co., 703 Colcord Bldg.

Meetings, Ninth Floor, Commerce Exchange Building: Technical Program, second Monday, each month, 8:00 P.M.; Luncheons, every Monday, 12:15 P.M.

SHAWNEE GEOLOGICAL SOCIETY
SHAWNEE, OKLAHOMA

President - - - - - - - - - - M. C. Roberts
The Texas Company
Vice-President - - - - - Robert L. Cassingham
Amerada Petroleum Corporation
Secretary-Treasurer - - - - - Martyna Garrison
Amerada Petroleum Corporation

Meets the fourth Monday of each month at 8:00 P.M., at the Aldridge Hotel. Visiting geologists welcome.

THE STRATIGRAPHIC SOCIETY OF TULSA
TULSA, OKLAHOMA

President - - - - - - - - - - Jerry E. Upp
Amerada Petroleum Corporation, Box 2040
Vice-President - - - - - - - Wendell S. Johns
The Texas Company
Secretary-Treasurer - - - - - Floyd L. Swabb
Sun Oil Company, Box 1348

Meetings: Second and fourth Wednesdays, each month, from October to May, inclusive, at 8:00 P.M.

TULSA GEOLOGICAL SOCIETY
TULSA, OKLAHOMA

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The Pure Oil Company, Box 271
1st Vice-President - - - - - John G. Bartram
Stanolind Oil and Gas Company
2nd Vice-President - - - - - Ronald J. Cullen
Sun Oil Company
Secretary-Treasurer - - - - - Herbert H. Kister
Stanolind Oil and Gas Company, Box 591
Editor - - - - - - - - - - John L. Ferguson
Amerada Petroleum Corporation
Associate Editor - - - - - - Hiram J. Tandy
Route 7

Meetings: First and third Mondays, each month, from October to May, inclusive, at 8:00 P.M., University of Tulsa, Kendall Hall Auditorium. Luncheons: Every Thursday (October-May), Michaelis Cafeteria, 507 South Boulder Avenue.

TEXAS

DALLAS PETROLEUM GEOLOGISTS
DALLAS, TEXAS

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DeGolyer, MacNaughton, and McGhee
Vice-President - - - - - - - - J. A. Lewis
Core Laboratories, Inc., Santa Fe Building
Secretary-Treasurer - - - - - Fred A. Joekel
Magnolia Petroleum Company, Box 900
Executive Committee - - - - Henry C. Cortes
Magnolia Petroleum Company, Box 900

Meetings: Regular luncheons, first Monday of each month, 12:15 noon, Petroleum Club, Adolphus Hotel. Special night meetings by announcement.

EAST TEXAS GEOLOGICAL SOCIETY
TYLER, TEXAS

President - - - - - - - - - Frank R. Denton
Consulting, 225 Owen Bldg.
Vice-President - - - - - - - - C. I. Alexander
Magnolia Petroleum Company, Box 780
Secretary-Treasurer - - - - - -G. J. Loetterle
Shell Oil Company, Inc., Box 2037

Meetings: Monthly and by call.
Luncheons: Every Monday at 12:00 noon, Blackstone Hotel.

TEXAS

FORT WORTH GEOLOGICAL SOCIETY
FORT WORTH, TEXAS

President - - - - - - - - - - Paul C. Dean
Consulting Geologist, W. T. Waggoner Building

Vice-President - - - - - - - - - C. L. Mohr
Ambassador Oil Corporation

Secretary-Treasurer - - - William J. Hilseweck
Gulf Oil Corporation, Box 1290

Meetings: Luncheon at noon, Worth Hotel, every Monday. Special meetings called by executive committee. Visiting geologists are welcome to all meetings.

HOUSTON GEOLOGICAL SOCIETY
HOUSTON, TEXAS

President - - - - - - - George S. Buchanan
Consulting Geologist, Esperson Building

Vice-President - - - - - - - - A. P. Allison
Sun Oil Company, Box 2659

Secretary - - - - - - - - - Leslie Bowling
Union Oil Company of California
1134 Commercial Building

Treasurer - - - - - - - - - Dugald Gordon
Brokaw, Dixon, and McKee, Gulf Building

Regular meeting held every Thursday at noon (12 o'clock) above Kelly's Restaurant, 910 Texas Avenue. For any particulars pertaining to the meetings write of call the secretary.

NORTH TEXAS GEOLOGICAL SOCIETY
WICHITA FALLS, TEXAS

President - - - - - - - - - - - - J. R. Seitz
Seitz, Comegys, and Seitz, 531 Waggoner Building

Vice-President - - - - - - - J. J. Russell, Jr.
Sinclair Prairie Oil Company
509 Hamilton Building

Secretary-Treasurer - - - - - - - J. M. Clark
Tide Water Associated Oil Company
924 Hamilton Building

Luncheons and evening programs will be announced.

SOUTH TEXAS GEOLOGICAL SOCIETY
SAN ANTONIO AND CORPUS CHRISTI
TEXAS

President - - - - - - - - - Fred P. Shayes
United Gas Company, Beeville

Vice-President - - - - - - - - - Gentry Kidd
Stanolind Oil and Gas Company, San Antonio

Secretary-Treasurer - - - - - Robert N. Kolm
1742 Milam Building, San Antonio

Executive Committee - - - - - - L. W. Storm

Meetings: Third Friday of each month alternately in San Antonio and Corpus Christi. Luncheon every Monday noon at Milam Cafeteria, San Antonio, and at Plaza Hotel, Corpus Christi.

SOUTHWESTERN GEOLOGICAL SOCIETY
AUSTIN, TEXAS

President - - - - - - - - - - H. B. Stenzel
Bureau of Economic Geology

Vice-President - - - - William A. Bramlette
Univ. Texas, Dept. of Geology

Secretary-Treasurer - - - - - - Travis Parker
Univ. Texas, Dept. of Geology

Meetings: Every third Friday at 8:00 P.M. at the University of Texas, Geology Building 14.

WEST TEXAS GEOLOGICAL SOCIETY
MIDLAND, TEXAS

President - - - - - - - - - Robert E. King
Shell Oil Company, Inc.

Vice-President - - - - - - - - Fred F. Kotyza
Tide Water Associated Oil Company, Box 181

Secretary-Treasurer - - - - Walter G. Moxey
Stanolind Oil and Gas Company

Meetings will be announced

WEST VIRGINIA

THE APPALACHIAN GEOLOGICAL SOCIETY
CHARLESTON, WEST VIRGINIA
P.O. Box 1435

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Ohio Fuel Gas Co., Box 117, Columbus, Ohio

Vice-President - - - - - Charles Brewer, Jr.
Godfrey L. Cabot, Inc., Box 348, Charleston, W.Va.

Secretary-Treasurer - - - - - - J. E. Billingsley
West Virginia Gas Corporation
Box 404, Charleston, W.Va.

Editor - - - - - - - - - Robert C. Lafferty
Owens, Libbey-Owens Gas Department
Box 1375, Charleston, W.Va.

Meetings: Second Monday, each month, except June, July, and August, at 6:30 P.M., Kanawha Hotel.

THE SOCIETY OF EXPLORATION GEOPHYSICISTS

President - - - - - - - - - H. B. Peacock
Geophysical Service, Inc., Houston, Texas

Editor - - - - - - - - - - - R. D. Wyckoff
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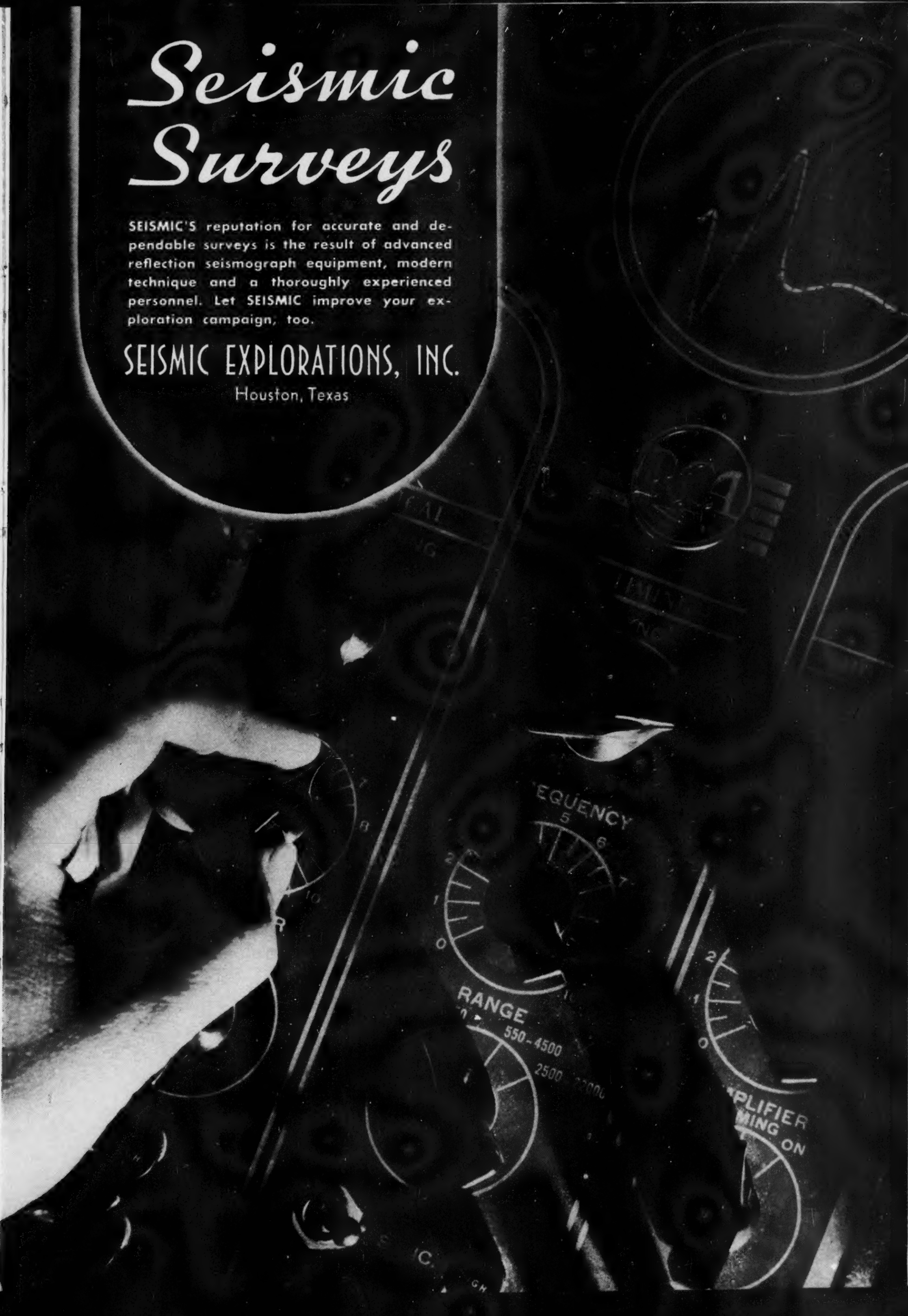
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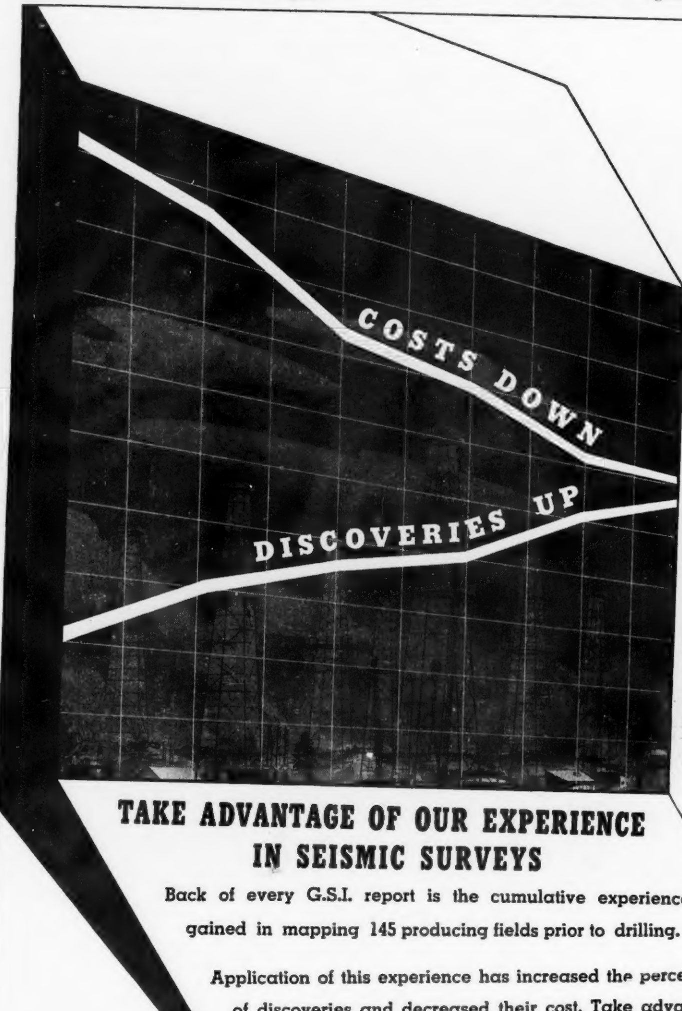

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